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Sales configurators as means to enhance sales-to-delivery processes of system products

Master's Thesis

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Instructor: Tero Muttilainen, M. Sc. (Tech.)

AALTO UNIVERSITY ABSTRACT OF THE MASTER'S THESIS
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This thesis aims to identify how industrial companies should use sales configurators in enhancing the sales-to-delivery processes of their system products. Sales configurators are software tools that support the definition of specific product individuals from the available variation range. This definition takes place in the sales phase, and the resulting specification is then used as input for manufacturing. Sales configurators are needed, in particular, with highly configurable system products, as management of the numerous options would otherwise become significantly complex. Academically, the study aims to provide new insights into system product sales configuration, while managerially, the objective is to provide recommendations on how companies, and especially the case company, should use sales configurators to achieve efficient system product configuration.

The research was conducted as a qualitative study consisting of a literature review, three benchmark case studies, and an extensive analysis of the case company. The reviewed literature covered the fields of sales configurators, supportive IT tools, and special characteristics of system product configuration. Further, the benchmark studies provided more in-depth insights into how sales configurators can be used in real-life corporate settings. To complement the literature and benchmark reviews, the system product configuration challenges of the case company were examined in detail. The data from each company case was collected through open-ended interviews: the benchmark companies were interviewed once, while altogether 81 interviews were conducted within the case company.

The main outcome of this thesis was the construction of a theoretical framework for identifying suitable actions to enhance system sales configuration with given sales configurator type. This framework suggested both short- and long-term actions for overcoming the existing sales configuration challenges, and could thus be used as both a starting point for further research on the topic and a general guideline for companies searching for enhancements in their system product sales configuration practices. In addition, the case company was given specific short- and long-term recommendations on how to enhance system product sales configuration practices.

Keywords: Sales configurator, system product, product configuration, sales-to-delivery process	Publishing language: English

AALTO-YLIOPISTO DIPLOMITYÖN TIIVISTELMÄ
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Tämän työn tarkoituksena on tunnistaa, miten teollisten yritysten tulisi käyttää myyntikonfiguraattoreita systeemituotteiden myynti-toimitusprosessien tehostamisessa. Myyntikonfiguraattorit ovat tuotteiden myyntivaiheessa käytettäviä ohjelmistotyökaluja, jotka tukevat tietyn tuoteyksilön määrittelyä tarjottavan variaatioavaruuden sisältä; näin syntyvää yksilöityä tuotemäärittelyä käytetään edelleen tuotteen valmistusprosessin perustana. Myyntikonfiguraattoreita tarvitaan erityisesti laajasti varioituvien systeemituotteiden kohdalla, sillä tuotevariaatioiden hallinnasta tulisi muutoin hyvin monimutkaista. Tutkimuksen akateeminen tavoite on avata uusia näkökantoja systeemituotteiden myyntikonfigurointiin liittyen, kun taas työn liikkeenjohdollisena tavoitteena on ohjeistaa yrityksiä, ja erityisesti case-yritystä, systeemituotteiden tehokkaan myyntikonfiguroinnin saavuttamisessa.

Työ toteutettiin laadullisena tutkimuksena, joka koostui kirjallisuuskatsauksesta, kolmesta benchmark-yritystutkimuksesta, ja varsinaisen case-yrityksen laajemmasta tarkastelusta. Kirjallisuutta käsiteltiin myyntikonfiguraattoreihin, konfigurointia tukeviin IT-järjestelmiin, ja systeemituotteiden konfiguroinnin erityispiirteisiin liittyen, kun taas benchmark-tutkimuksissa tarkasteltiin yksityiskohtaisemmin myyntikonfiguraattoreiden käyttöä oikeissa yritysympäristöissä. Kirjallisuuden ja benchmark-tutkimusten lisäksi systeemituotteiden myyntikonfigurointikäytöntöjä tarkasteltiin laajemmin case-yrityksen tapauksessa. Yritystutkimukset toteutettiin avoimina haastatteluina: jokaista benchmark-yritystä haastateltiin kerran, kun taas case-yrityksessä toteutettiin yhteensä 81 haastattelua.

Työn tärkeimpänä löydöksenä muodostettiin teoreettinen viitekehys, jonka avulla voitiin tunnistaa kuhunkin myyntikonfiguraattorityyppiin sopivat systeemituotteiden myyntikonfigurointia edesauttavat toimenpiteet. Viitekehys sisälsi konfiguroinnin tehokkuutta edistävät toimenpide-suositukset niin lyhyelle kuin pitkälle aikavälille: näin ollen viitekehys soveltui lähtökohdaksi aiheeseen liittyville jatkotutkimuksille ja yleiseksi ohjeistoksi systeemituotteiden myyntikonfiguroinnin tehostamista tavoitteleville yrityksille. Lisäksi työssä annettiin tarkemmat konfigurointikäytäntöihin liittyvät suositukset case-yritykselle, niin lyhyelle kuin pitkälle aikavälille.

Asiasanat: Myyntikonfiguraattori, systeemituote, tuotekonfigurointi, myynti-toimitusprosessi	Julkaisukieli: englanti

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Most importantly, writing this thesis was an educational and finally even rewarding process. However, it was also long, laborious, and difficult: the idea of finalizing this thesis was not the first issue in mind when five months of this eight month process had passed and I had basically not written a word of the actual thesis: for long, it was not clear what the specific topic of this thesis would be. Furthermore, even after finally writing the first drafts of this document, the situation did not turn especially optimistic: I was asked to rewrite majority of the text and compress the result into a half of the original content. In retrospective, the hundreds of hours spent for this thesis were worth it, but at many points it certainly did not feel so.

Despite the challenges experienced along the way, and perhaps particularly because of them, I would like to thank multiple admirable people for their help within this process. First and foremost, I am grateful to the case company for providing me with the opportunity to conduct this thesis project in the first place. In particular, I wish to thank my instructor Tero Muttilainen and a few other case company members, Tommi L. and Heikki J., for excellent guidance throughout this challenging project. Furthermore, I would like to express my gratitude to my supervisor, Professor Eero Eloranta for constantly pushing me to sharpen the thesis content and especially for making this a certainly memorable journey: his colorful and honest comments, such as "to solve the challenge of this demanding topic, you might need to be able to pull a rabbit from your hat", made the supervision sessions particularly fruitful.

In addition, I would like to thank my friends for reminding me that there is a life outside the computer screen, and especially my family for always being there for me. Finally, I want to thank you, Silja, for your relentless support and patience during this challenging and long-lasting process.

Jouko Heiskanen

Helsinki, October 2012

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1 Introduction

This study examines how sales configurators can be used in optimizing the sales-to-delivery processes of industrial companies. The emphasis is especially on quote creation phase, and more precisely on how sales configurators can be utilized in configuring complex, customizable system products. The research was conducted as a multiple case study in four Finnish ICT companies, with the emphasis on the situation of one of the companies, Case Company. This chapter is divided into six subchapters: First, the concept and need of product configuration is discussed as background for the thesis topic. Second, the research scope and context are presented, and third, the research questions of the study are introduced. Then, the objectives and methodology are discussed, and finally, the structure of the study is presented.

1.1 Background

When introducing the famous "model T" car model in 1908, Henry Ford remarked that "any customer can have a car painted any color that he wants so long as it is black". In that era, Ford's revolutionizing approach of mass production, including high productivity and low cost level, was the key differentiating factor between the manufacturer and its competitors. However, during the following 100 years, the situation has changed significantly: customers do not accept non-customized bulk products anymore. (Smil, 2005) Instead, the ability to provide individually tailored products has become increasingly important. In addition, despite their desire for customization, customers still require low price and lead time levels similar to traditional mass production. As a result, companies face a difficult challenge: they should be able to combine efficiency of mass production with customizability of individual tailoring. (Blecker et al., 2007)

The most well-known approach to solve this tradeoff is called *mass customization*: this business strategy is based on the idea to split a product and its variants into mass-producible modules, which can then be efficiently combined according to customer's specific needs. (Pine, 1993) However, as this modular solution notably increases the complexity of managing and modeling the product variety data, the

profitable implementation of mass customization strategy has proven to be a difficult task (Harju, 1999). Typically the most optimal way to solve this complexity challenge has been adaptation of supportive computer systems, which can streamline data management and support product variant definition. (Skjevdal et al., 2005) The main task of these software solutions, called *product configurators*, is to convert customer requirements into technical product specifications. More specifically, product configurators typically consist of two elements: *sales configurators*, which convert customer's functional product requirements into a sales specification, and *production configurators*, which in turn convert the functional level sales specification into corresponding technical item codes. (e.g. Tiihonen and Soininen, 1997; Forza and Salvador, 2002) As the success of the latter conversion depends only on internal ability to link the sales and production specifications, the most important element of product configuration can be said to be the sales configuration phase: if the customer requirements can be efficiently converted into a form easily controllable by the company, the sales configurator has succeeded in its crucial task to produce a desired input for the overall sales-to-delivery process. (Tiihonen et al., 1998)

However, there are multiple challenges to be solved before achieving a successful product configuration process: First, as customers typically see the product "in almost entirely different light" than e.g. manufacturing (Männistö, 1998), it is a considerable challenge to create suitable linkages between the functional options seen by customer, and the technical item codes needed by production. Second, as the configurator is only one of multiple corporate IT tools, including e.g. product data (PDM) and production management (ERP) systems, there is a need to integrate the configurator with the other tools. (Tiihonen et al., 1996) Although solving either one of these challenges is not a straightforward task, there is a considerably limited amount of research covering these issues (Tiihonen et al., 1997; Skjevdal et al., 2005). Thus, this study aims to provide more light into the challenges of sales configuration and the role of product configurators in corporate IT infrastructures. In addition, as the product configuration research has mostly concentrated on single configurable products, this thesis targets to extend the research scope into special

characteristics of configuring more complex system products, which consist of multiple configurable components.

1.2 Research context and scope

The context of this thesis is in Finnish ICT industry. The empirical data is gathered from three benchmark companies, Benchmark Company 1, Benchmark Company 2, and Benchmark Company 3, and one extensively studied case company, Case Company. Although the case studies are conducted in these specific companies, the aim of this study is to provide generalizable knowledge on how should product configuration be executed in any industrial company providing system products: more specifically, the company cases are ultimately used as examples on how to execute system configuration given the boundaries of each company's configuration environment.

In general, the scope of this study is to identify requirements and suitable approaches for efficient system product configuration. In more detail, the emphasis is on companies which not only offer system products, but also the components of these systems (e.g. a car manufacturer which also sells car engines): this type of multi-level product offering was taken as the specific emphasis due to its presence in the thesis' primary case company, Case Company. Consequently, this requirement was also used when selecting suitable benchmark companies to complement the Case Company study. Overall, the literature review, the benchmark cases, and the Case Company case study aim to form generalizable knowledge on how should system product configuration be implemented in industrial companies pursuing this multi-leveled offering of both products and systems.

1.3 Research questions

This main focus of this study is on utilizing product configurators to optimize the sales-to-delivery processes of industrial companies. The interest is particularly on the sales phase, more precisely on configuring (i.e. quoting) complex, customizable system products. The main research question is defined as follows:

> *How should industrial companies use sales configurators in enhancing their sales-to-delivery processes of system products?*

The main research question can be divided into three sub-questions:

1. *What are the general benefits and challenges of using sales configurators?*
2. *How should sales configurators be integrated with other corporate IT systems?*
3. *What special characteristics are related to achieving efficient sales configuration of complex, configurable system products?*

These research questions are addressed with a literature review, three comparative benchmark studies (Benchmark Company 1, Benchmark Company 2, and Benchmark Company 3) and an extensive case study of Finnish high-tech company Case Company. Although these parts aim to complement each other when answering the research questions, each part have also their own specific emphasis: The literature review aims to especially highlight the general issues related to the usage of product configurators in the sales phase, while the benchmark studies target to provide light for integrating configurators to corporate IT infrastructure. Finally, the case study of Case Company aim to focus on the special characteristic of system product configuration.

1.4 Objectives

The main objective of this study is to provide recommendations for industrial companies on how to utilize sales configurators in enhancing their entire sales-to-delivery processes. In addition to the general recommendations, a more focused objective of the study is to suggest enhancements for the sales configuration setting in the Case Company. More specifically, the objectives of this study can be divided into two categories, academic and managerial objectives:

1. **Academic objectives**: This study aims to provide new insights into the usage of sales configurators as enablers of efficient sales-to-delivery processes, especially in the case of complex system products.
2. **Managerial objectives**: This study targets on providing recommendations for industrial companies on (i) how to utilize sales configurators in general, (ii)

how to integrate sales configurators in the corporate IT infrastructure, and (iii) how to implement the sales configuration of complex, configurable system products. Although the general aim is to provide recommendations for any industrial company, the main objective is especially to recommend enhancements for the specific system configuration challenges of the Case Company, taking into account the boundaries of its sales configurator implementation and other configuration-related issues.

1.5 Methodology

This research is conducted as a qualitative study consisting of a literature review, three benchmark case studies, and an extensive study of a case company. The literature review forms a theoretical background related to system product configuration: consequently, also according to the study targets formed in the research questions, the reviewed literature is gathered from the following three streams: (1) Mass customization and configurable products (led by e.g. Pine, 1993; Ulrich and Eppinger, 1995; Heiskala et al., 2009), (2) Product configurators and related IT infrastructure (led by e.g. Tiihonen and Soininen, 1997; Arana et al., 2007), and (3) Special configuration-related characteristics of system products (led e.g. Hobday, Davies, and Prencipe, 2005; Kropsu-Vehkaperä et al., 2011). Overall, more than 50 literature sources, consisting mostly of academic journal articles and books, are reviewed during the theory chapter.

Further, to complement the literature review, three benchmark case studies are conducted: as the specific aim of the benchmarking part is to understand how the configuration-related IT infrastructure is constructed in these companies, the studies are implemented by interviewing managers responsible for each company's sales configuration practices (see Appendix for list of interviews). The interviews are semi-structured, consisting of open-ended questions. Finally, the extensive study of the Case Company is conducted by conducting over 80 interviews from personnel across the organization: however, the interviews are most importantly focused to the managers of Case Company's certain system product area, as the majority of the system products and related configuration challenges are concentrated on these products. A significant emphasis is given also to the interviews of IT tool experts

responsible for the configuration-related IT infrastructure. In addition, Case Company's internal documents are significantly utilized and the existing configuration tools tested to understand the challenges also in practice.

1.6 Structure

This study is divided into seven chapters: After this introductory chapter, a comprehensive literature review is presented. The review covers topics of mass customization and configurable products, product configurators and the need for multiple configurator views, linkages between configurator and other IT tools, and the special characteristics of configuring system products. After the theoretical review, the benchmark case studies are presented, including description of the system configuration process and evaluation of the overall practices. Then, the 4th chapter summarizes the combined findings from both the literature review and the benchmark cases, and provides a general framework for issues related to achieving efficient system product configuration. The 5th chapter presents the extensive study of the Case Company: After a brief introduction to the configuration environment of the company, its current problem is described with discussion on the problem causes. Then, currently available approaches for enhancing the problematic system configuration are evaluated, and lastly, suitable short- and long-term solutions are recommended for the case company. The 6th chapter provides discussion on the study's findings, including general recommendations for industrial companies willing to enhance their system product configuration practices. Finally, the 7th chapter provides conclusions by summarizing the key findings, evaluating the study and considering suitable topics for future research.

2 Literature review

This chapter provides a review of the literature covering product configuration, starting from the concept of mass customization and configurable products. The chapter continues with an introduction to product configurators and their general benefits and challenges. Further, the viewpoint is focused on using product configurators in the sales phase: especially the differences between the needs of sales and manufacturing are covered. In addition, general issues related to the role of product configurators in the corporate IT infrastructure are discussed. Lastly, the special characteristics of selling and configuring complex system products are researched.

2.1 General requirements for successful product configuration

This subchapter discusses the general requirements which need to be fulfilled to achieve successful product configuration. The subchapter is divided into two parts: first, the need for restructuring product to support the requirements of mass customization strategy is covered, and second, the need for employing a product configurator software is discussed.

2.1.1 Restructuring products to support mass customization

The approach of configuring products to match specific customer needs is one of the major building blocks of the mass customization strategy. More specifically, mass customization's targets of combining efficiency of mass production and customizability of individual tailoring can typically be most successfully implemented by product modularity principles. (Pine, 1993) By dividing product individuals into predefined, interchangeable modules, both efficient mass production and flexible, case-specific combining of these modules are enabled. Thus, the most important single issue in achieving successful mass customization is rebuilding product structures and other related product information to support configurability. (Forza et al., 2002) In the following sections, the approaches of modular product architectures and configurable products are discussed in more detail.

Fit between modular product architecture and mass customization

The term *product architecture* describes products from two viewpoints: (1) manufacturing view, which represents the physical composition of a product ("what does the product consist of"), and (2) customer / sales view, which represents the linkage from the physical blocks to the product's functional elements ("what can the product do"). (Ulrich et al., 1995) As the requirements of these views are typically significantly differing, it is challenging for any product architecture solution to fully support the needs of both parties. (Arana et al., 2007) As a result, there are two general, distinctive alternatives for product structuring: (1) modular architecture, in which the structures are especially designed for easy composition and manufacturing, and (2) integral architecture, in which the structures are created with performance orientation and thus customer needs in mind. The differences between these architecture alternatives are illustrated in Figure 1 below (adapted from Ulrich, 1995 & Ulrich and Eppinger, 1995).

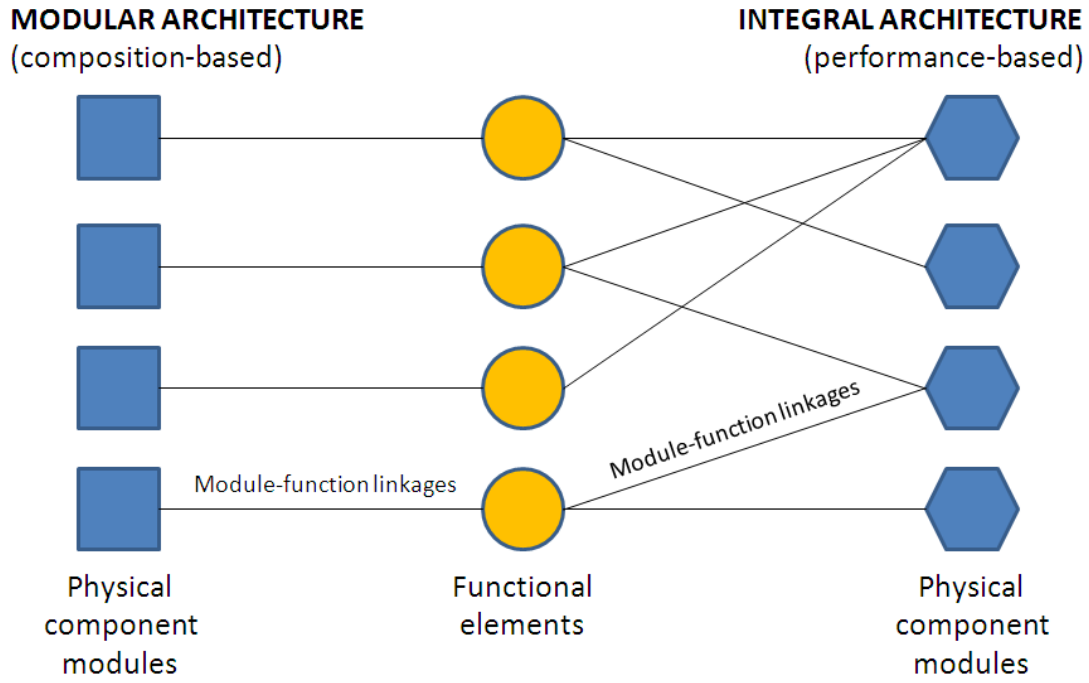

Figure 1 – Differences between modular and integral architectures

As can be seen from the figure, both product architectures are based on the idea to create a product entity by combining multiple physical component modules. However, there are certain differences in how the modules are defined, and how they

are linked to the functional elements: In modular architecture, one component module is specified so that it would be easy to manufacture. In addition, it targets to keep relationships between the modules and functional elements considerably simple, thus enabling easy module changes. (Ulrich, 1995) On the other hand, integral architecture defines component modules from performance point of view: to optimize product's functionalities, the idea of easy manufacturing is not considered a primary issue; instead, the emphasis on creating enhanced functionalities by using multiple component modules to create the functional elements. Although the performance can thus be optimized, manufacturing and module changing becomes significantly more difficult. (Salvador et al., 2004) Overall, as successful mass customization is especially based on easily customizing products from multiple efficiently producible components, the alternative of modular product architecture clearly provides a better option for the needs of this strategy. (Tiihonen et al., 1997)

Configurable products as concrete enablers of mass customization

As discussed in the previous section, modular product architecture typically provides the best fit for mass customization's configurability needs. However, the architecture selection in itself is only a prerequisite for achieving the benefits of the business strategy: it only provides basis capability for customization. (Tiihonen et al., 1998) To actually be able "put the 'mass' in mass customization", the available component module range needs to be clearly predefined, controlled, and illustrated to the customers (Blecker et al., 2005). These targets are typically achieved by taking the approach of *configurable product structures*, which explicitly specify the available modules and their combination rules for each product. More specifically, Tiihonen and Soininen (1997) define configurable products to have the following properties:

- Pre-designed to meet a given range of different customer requirements
- Individually tailored for customer-specific needs
- Combination of pre-designed components or modules
- Pre-designed general structure / architecture
- No creative or innovative design needed during the sales-to-delivery process, only routine product instance specification

These specifications clearly differentiate configurable products from both standard (mass-produced) and one-of-a-kind products: the properties related to pre-designed component range mark that the target is not to fulfill every possible customer needs, while the tailoring and combining related properties highlight that each configurable product contains certain level of customization. Thus, configurable products provide a great fit with the needs of mass customization strategy: they combine approaches from both mass production and individual tailoring. (Heiskala et al., 2009) A comparison between configurable products and the other two product types is presented in Figure 2 below (adapted from multiple sources: e.g. Pine, 1993; Tiihonen & Soininen, 1997).

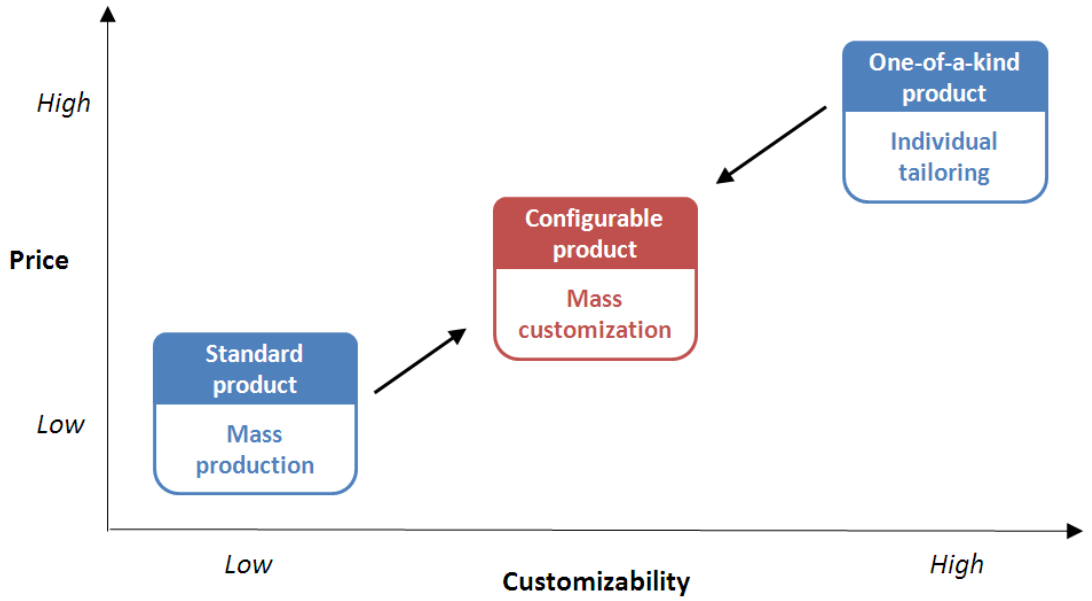

Figure 2 – Configurable products compared to mass- and one-of-a-kind products including suitable business strategies per product type

From the figure it can be seen that configurable products are in the middle of both customizability and pricing axes when compared to mass and one-of-a-kind products. Especially, configurable products have higher prices than mass-produced goods due to the customization need, even though the configurability range is limited. The relationship is similar than with the corresponding business strategies in general: mass customization's costs can be kept under control, but it is not possible to retain the same low-cost level than with mass production. (Skjevdal et al., 2005)

2.1.2 Using product configurator to streamline product-related processes

As discussed in the previous subchapter, the creation of configurable products structures makes it possible to efficiently control the customizable product variants. However, to be more precise, the configurable structures only provide input for product customization: to be able to actually use the component data and the validity checking rules between them, a computerized system is almost always needed to collectively manage and streamline the configuration-related tasks. (Tiihonen et al., 1996) These information system support tools are called *product configurators*, and they basically act as a user interface for the configurable product structures (Tiihonen et al., 1997). Thus, configurators are stated to be the most important enablers of the mass customization strategy (Blecker et al., 2007; Jannach, 2011). More specifically, the main task of product configurators is to provide assistance in creating a desired product individual; in other words, these support tools are responsible for the conversion from customer requirements all the way to technical item codes. (Franke et al., 2002) The next sections discuss the elements of this conversion process and the role of product configurators in the sales-to-delivery process in general.

Elements of product configuration and configurator systems

As discussed, through the usage of product configurators the customer requirements can be efficiently converted to a technical product individual specification. Although the ultimate target of this conversion is to achieve a correct list of technical item codes to be produced, the configuration process begins with the gathering of customer requirements. (Aho, 2008) Further, as customers tend not to view the products from technical item viewpoint, but from a more functional perspective, the configurator user interface cannot consist of these technical items. Instead, a more customer-friendly product view with functional and more abstract level specifications is typically needed to ensure that customers understand the content and consequences of each configuration selection. (Tiihonen, 1999; Arana et al., 2007) As a result, the configuration task is split into two adjacent phases: (1) sales and (2) production configurations. The first configuration converts customer requirements into functional sales items, while the second configuration turns the sales feature items into technical items. (Forza et al., 2001)

Further, both these tasks are supported by a product configurator; however, as supporting the separate tasks requires also separate functionalities, the configurator support is typically divided into elements of sales configurator and production configurator. As the configurator element names indicate, the first element is responsible for creating the sales specification, while the second produces a manufacturing specification. (Arana et al., 2007; Algeo et al., 2007) More specifically, both of these elements take two inputs and produce a single output: first, sales configurator matches customer requirements with functionality-describing sales items and configuration (e.g. validity checking) rules between them, and creates a list of configured sales items. Second, in the production configurator phase, this list is combined with the corresponding technical item definitions (the linkage between sales and technical items is sometimes predefined), thus resulting in a list of configured technical items. (Forza et al., 2001) This configuration process from customer requirements to technical items is illustrated in Figure 3 below (adapted from multiple sources: e.g. Tiihonen and Soininen, 1997; Arana et al., 2007).

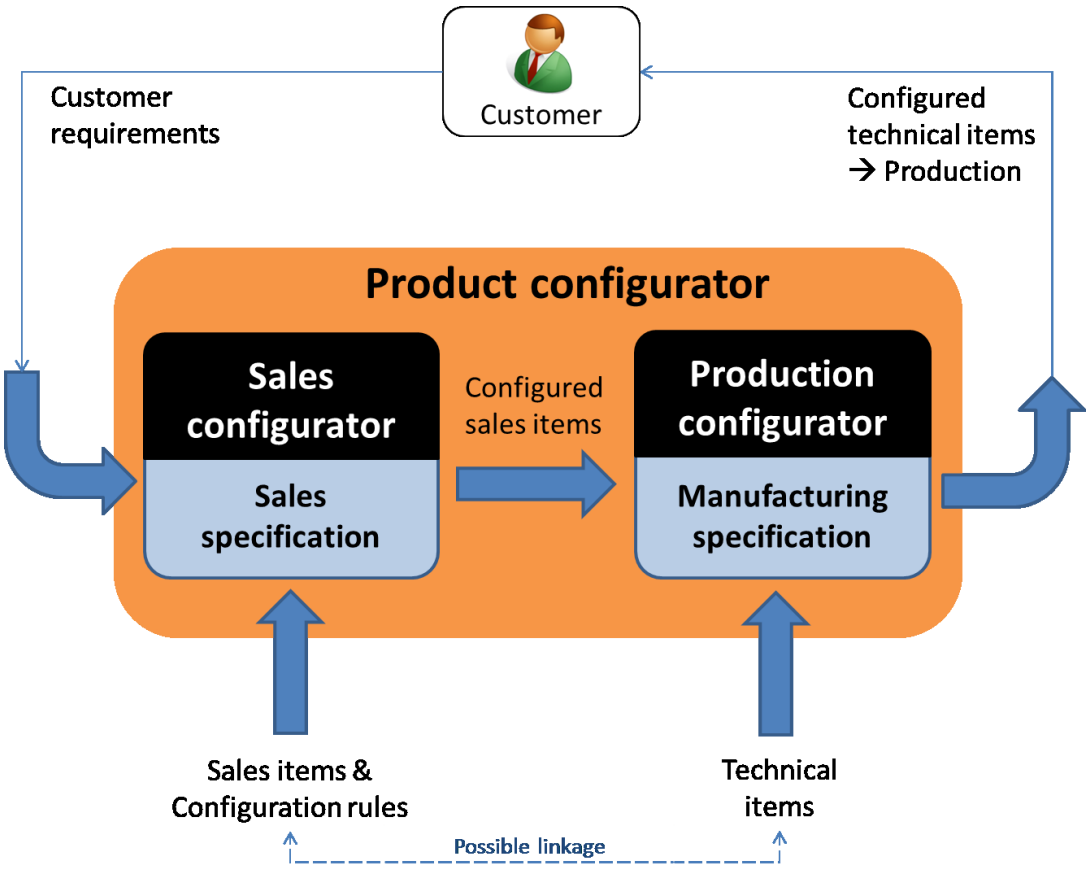

Figure 3 – Product configurator elements and related inputs for each configuration phase

Role of product configurators in the sales-to-delivery process

As highlighted in the above figure, product configurator has a crucial role in converting the customer requirements into producible list of technical items. However, to fully understand the whole process from sales to delivery, a deeper analysis of the role of product configurators as part of this process is needed. In general, the sales-to-delivery process of configurable products includes the phases of (1) sales specification, (2) manufacturing specification, (3) manufacturing, (4) assembly, and (5) delivery. (Tiihonen et al., 1998) As discussed, the product configurator is an essential tool in the configuration process which covers the first two phases. Further, it provides the output for the remaining production process, which consists of phases from manufacturing to delivery. (Soininen, 2000) In addition to the sales-to-delivery process, a supporting product development process is required to provide inputs for the product configurator. This process includes designing the product and defining required items for both manufacturing and sales use. (Tiihonen et al., 1997) The specified items are linked to sales and production configuration phases as was illustrated in Figure 3 above.

More specifically, the entire sales-to-delivery process and the supportive product development process are presented in Figure 4 below (adapted from multiple sources: e.g. Tiihonen et al., 1998; Soininen, 2000). As can be seen from the figure, the product configurator, including its sales and production configurator elements, form the heart of the process of configurable products: configurator takes inputs from both customers and item descriptions, and produces a correct output to be used in the rest of the process. (Freuder, 1998; Tiihonen et al., 1998) The figure highlights the importance of the sales configuration phase, as that phase covers the most difficult task of the entire process: converting customer needs into explicit item specifications needed for internal process phases. If the sales configuration can be created correctly in the first place, the rest of the process is straightforward to streamline and automate. (Soininen, 2000; Tenhiälä et al., 2012) In addition, from the configuration point of view, the definition of technical and sales items and especially the linkage between them poses another challenge for continuing the process after the sales

specification has been made (Arana et al., 2007). This sales-to-production conversion issue is further discussed in subchapter 2.2.2.

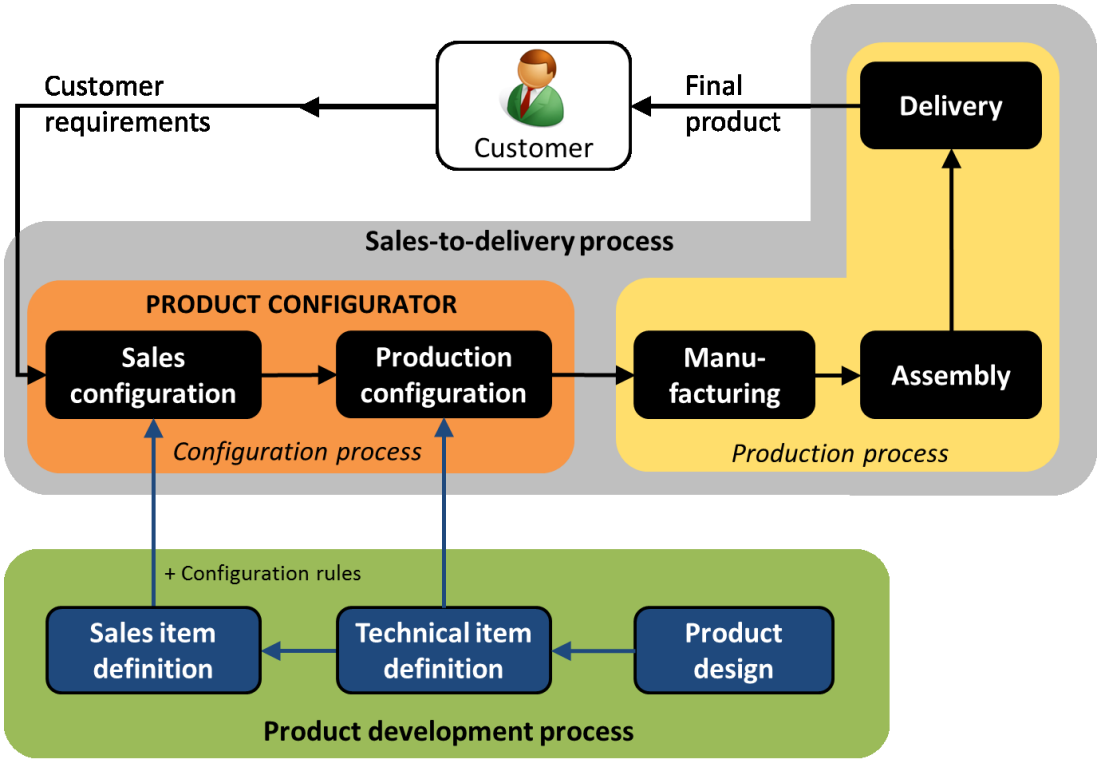

Figure 4 – The role of product configurator in the sales-to-delivery process of configurable products

2.2 Sales configurator as an enabler of efficient sales-to-delivery

As discussed above, the most important phase of product configuration related processes is creating a correct and explicit sales specification from customer requirements. Thus, it is important to study how the sales configuration phase, which is mainly supported by a sales configurator, should be implemented to achieve a successful overall sales-to-delivery process. This subchapter covers the analysis of general benefits and challenges related to the usage of sales configurators. In addition, the need for creating separate product views for sales and production, including different approaches for linking these views, is discussed.

2.2.1 Benefits and challenges of sales configurators

The importance of product configurators in general is a widely popular research area, and consequently the benefits and challenges related to their usage are covered in

multiple studies (Tiihonen et al., 1998; Skjevdal et al., 2005; Hvam et al., 2010). However, although both the benefits and challenges are typically related to sales configuration phase in particular, the specific issues related to sales configurators are seldom separated from the general product configuration viewpoints. The specific importance of sales specification phase can also be reasoned through quantitative data gather in certain studies: for example, in their study of 10 Finnish manufacturing companies in 1998, Tiihonen et al. reported that typically "about 80 % of the sales configurations are incomplete, and about 50 % of them contain errors". Meanwhile, McHugh (1996) estimated that in the U.S., manufacturing companies lose 1-2 % of their annual revenue due to these sales specification errors. As a result, this subchapter targets the focus especially on the benefits and challenges of sales configuration and thus sales configurators, despite the fact that most of these issues overlap with general product configuration topics.

General benefits of employing a sales configurator

Although there are numerous benefits that relate to using sales configurators, the majority of them can be linked to six most important benefit categories: productized offering, sales efficiency, production efficiency, knowledge distribution, customer satisfaction, and general financial impact. These main pros are presented in Figure 5 below (combined from multiple sources: e.g. Forza and Salvador, 2002; Hvam, Pape, and Nielsen, 2006; Heiskala, 2009), and discussed further per category.

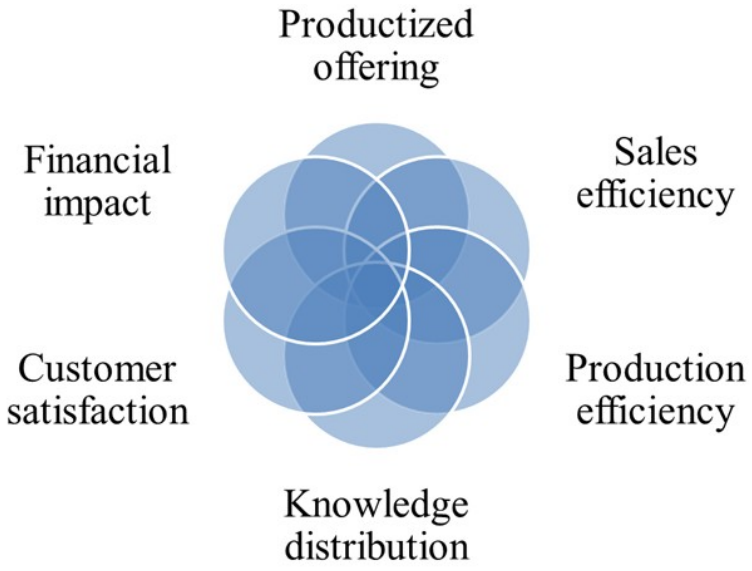

Figure 5 – General benefits related to employment of a sales configurator

Productized offering: The employment of sales configurator requires gathering and modularizing all product-related information. This systematization leads to significantly better productized product offering, which in turn simplifies and streamlines all product and item management. (Hvam et al., 2010) In addition, modularization enables easy cross-usage of component modules, thus reducing unnecessary redundancy. (Heiskala et al., 2009)

Sales efficiency: Most parts of the sales process can be automated, thus eliminating the difficult tasks of validity checks and reducing the amount of human errors. As the configuration gets easier, the number of quotes can be increased, thus improving the sales opportunities. (Hvam et al., 2006)

Production efficiency: Amount of erroneous sales specifications reduces, thus applying straightforward manufacturing without multiple iterations in correcting the invalid configurations. Thus, the lead-times of even the more complex products can be significantly cut. (Hvam et al., 2010)

Knowledge distribution: As employing a sales configurator requires explicit definition of product and configuration knowledge, the information can be effectively maintained and distributed across different parts of the organization. Thus, the dependence of product experts in each phase is reduced and capacity is freed for more value-adding tasks. (Tiihonen et al., 1998; Skjevdal et al., 2005)

Customer satisfaction: Through configurator, the customer can receive easier access to the products and related options, reduced delivery times, more reliable on-time deliveries, possibly enhanced quality (through process streamlining) and reduced prices (through efficiency). (Franke et al., 2003; Skjevdal et al., 2005)

Financial impact: Higher number of quotations and easier conversion of quotes to technical items directly increase sales volumes. Process-streamlining and enhanced production control reduces costs, while the systemized product offering makes it possible for sales to direct customers to internally most easily producible, profitable component combinations. (Skjevdal et al., 2005; Heiskala et al., 2009)

General challenges of employing a sales configurator

In addition to the multiple benefits provided by sales configurator usage, there are certain challenges to be considered as well. The most important challenges, including

customer need identification, product modularization, sales feature definition, sales-production linkage, process realignment, and IT infrastructure integration, are illustrated in Figure 6 below (combined from multiple sources: e.g. Tiihonen and Soininen, 1997; Skjevdal and Idsoe, 2005; Heiskala et al., 2009).

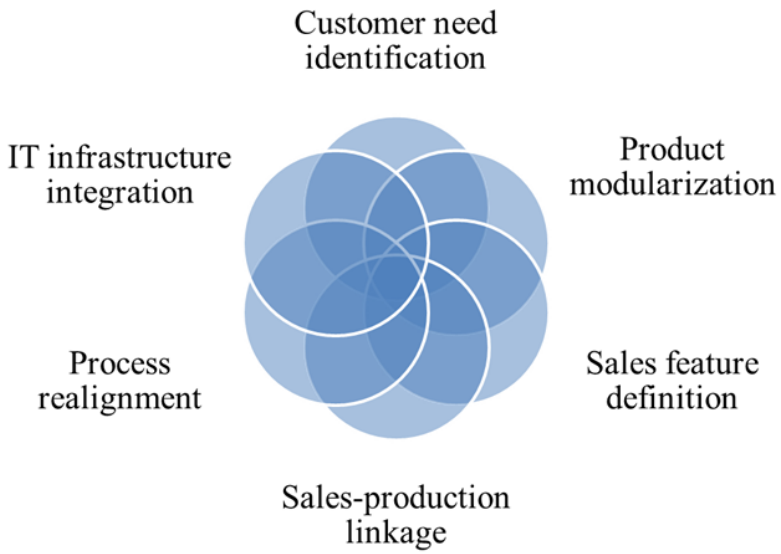

Figure 6 – General challenges related to employment of a sales configurator

Customer need identification: First, achieving successful sales configuration requires clear identification of customers' needs. Misfit between product specifications and customer needs is one significant factor behind erroneous sales specifications. (Heiskala et al., 2009)

Product modularization: Adopting modular product architectures and creating suitable configurable structures is a challenging and typically somewhat expensive task (Pine, 1993). Further, without clearly predefined available product range, sales configuration creation becomes significantly complex as components need to defined manually. (Tiihonen et al., 1997)

Sales feature definition: Typically companies can explicitly define the technical components required for sales configuration; however, the definition of customer-friendly sales features might be a difficult task for companies focusing on internal production requirements. (Ulrich et al., 1995; Arana et al., 2007)

Sales-production linkage: A considerable challenge for sales configuration phase is the ability to link the sales specification to technical items needed in production.

(Forza et al., 2002; Arana et al., 2007) Different alternatives for this linkage are further discussed in subchapter 2.2.2.

Process realignment: The employment of a sales configurator typically requires considerable realignment of company's business processes: although configurators in the end streamline and automate the process, the process needs to first be reorganized to support configurability needs. (Haag, 1998; Tiihonen, 1999)

IT infrastructure integration: In general, sales configurators cannot function successfully without proper interaction with other corporate IT systems such as PDM and ERP, as these systems store the configurator inputs and use its outputs. (Skjevdal et al., 2005)

2.2.2 Need for separate sales and manufacturing views

As product configuration tasks can be split into sales and production configuration creation, it is clear that both these phases require different information of the configurable product in question. In general, the need to provide multiple product views is stated to be one of the main challenges when trying to optimize the sales-to-delivery process (Arana et al., 2007) More specifically, the requirements of these phases differ especially on their scope and level of abstraction: Sales configuration phase, i.e. a sales view, requires information designed for customer needs, which typically concentrate on the functional, performance-oriented features and commercial product information, such as pricing. (Hvam, 1999) On the other hand, the production configuration phase, i.e. a manufacturing view, should include information understandable to company's production; product and related items are defined in physical, technical level, so that manufacturing can be started explicitly. (Männistö, 1998)

The discussed differences between these views are highlighted in Figure 7 below (adapted from Arana et al., 2007). As discussed, providing these separate views is typically a challenging task: however, to be more precise, plainly defining the needs of sales and manufacturing for a certain product is not difficult; instead, the interaction and linkage between the sales and manufacturing specifications is the key challenge when forming these separate views. (Arana et al., 2007) The following

sections discuss different alternatives for linking the views, and extend the investigation on varying requirements for a single product view.

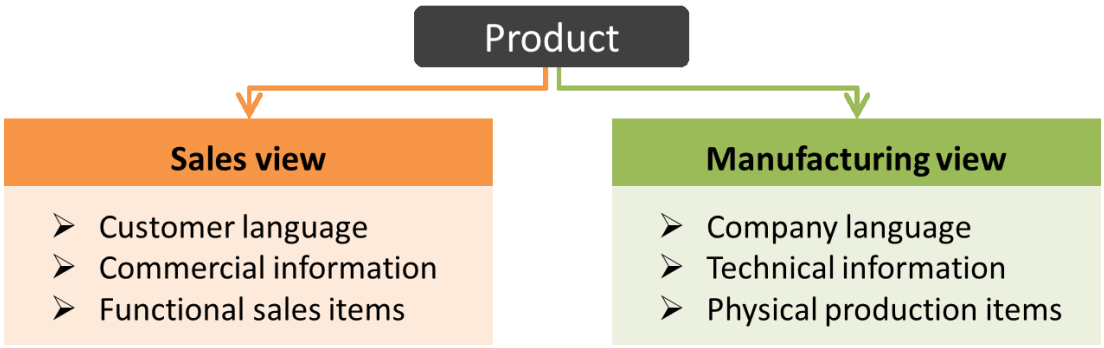

Figure 7 – General differences between sales and manufacturing product views

Alternatives for linking sales and manufacturing views

As the configuration process begins with sales specification creation which is then converted into a manufacturing specification, it is clear that the views within these specifications are created need to be connected with each other. As both the views represent one viewpoint of a same product, linking the views is an issue of product modeling: the sales view consists of the sales items related to the product, while the manufacturing view is built with technical items. As products in general are typically modeled with a product structure, i.e. its bill-of-materials (BOM), the separation of the views is usually done with creating the BOM structures from the mentioned sales and technical items. The need for these combined BOM solutions is especially high with complex, configurable product structures with numerous options, as the BOM management easily becomes overly laborious: this challenge is especially highlighted by Männistö (1998), who state that with complex product, "it is no longer possible to survive with traditional methods such as [single, fixed] BOM lists". Further, the possible approaches for modeling products with both sales and technical items include the following:

1. **Using a single BOM for both sales and technical items:** from the structure, only relevant hierarchical are shown for each user group (Stonebraker, 1996; Tiihonen et al., 1998; Männistö et al., 2001)

2. **Using multiple BOMs (separated sales and manufacturing BOM):** sales BOM's items are linked with corresponding technical items of the manufacturing BOM with certain logic rules (Mortensen et al., 1999; Arana et al., 2007; Shamsuzzoha et al., 2011).

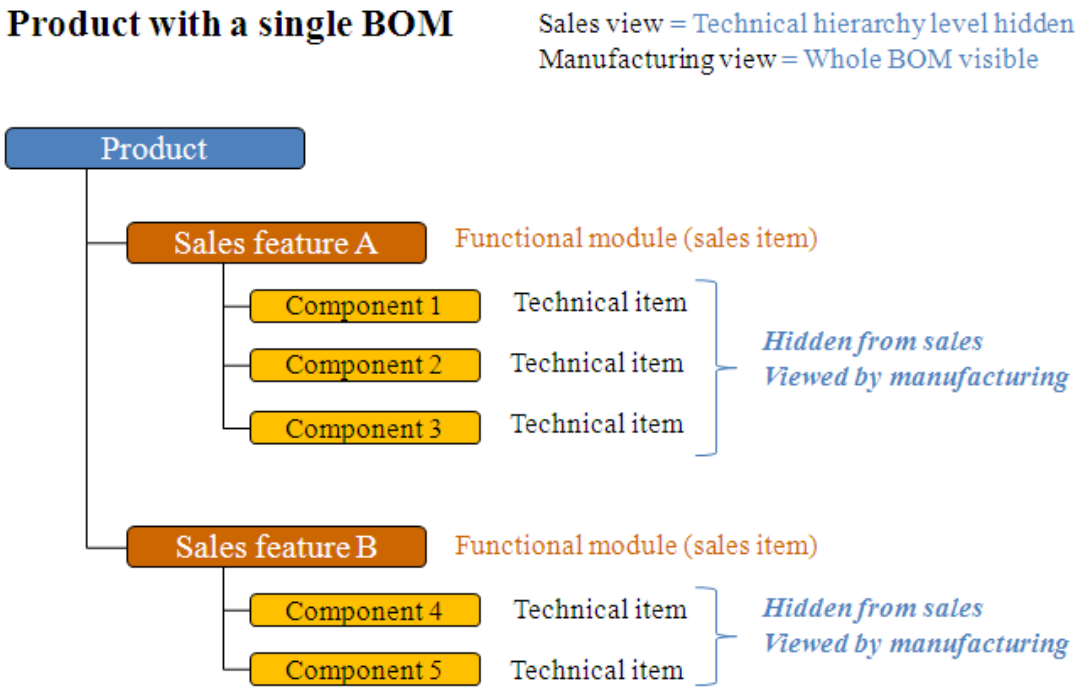

Figure 8 – Product modeled with a single bill-of-material: sales and manufacturing views are created by showing only relevant hierarchical levels

The differences between these solutions are illustrated in Figure 8 (above, adapted from multiple sources: e.g. Stonebraker, 1996; Männistö et al. 2001) and Figure 9 (below, adapted from multiple sources: e.g. Mortensen and Hansen, 1999; Arana et al., 2007). As can be seen from the figures, the single BOM approach contains a single hierarchical list of needed technical items, which are grouped under functional modules representing the sales items. This approach suits well to products which sales modules directly represent certain technical item combinations (Stonebraker, 1996): this is typically the case with somewhat simple product without complex relationships between its components. However, with more complex products and larger structures, the management of numerous items under the same structure easily becomes overly laborious, inflexible, and heavy. (Männistö et al., 2001) On the other

hand, the multiple BOM approach clearly separates the sales and manufacturing items into two BOM structures, which are linked with each other. Thus, the solution is more lightweight from the maintenance point of view, as the BOMs consist of fewer items. (Mortensen et al., 1999) More importantly, it allows creating both views purely for the specific needs of each party, without the need to consider which technical items should be assembled together with a specific sales module selection. However, the approach of multiple BOMs always includes the need to define linkages between the BOM items, thus leading to unnecessary relationship complexity in case of somewhat simple products with few modules. (Arana et al., 2007)

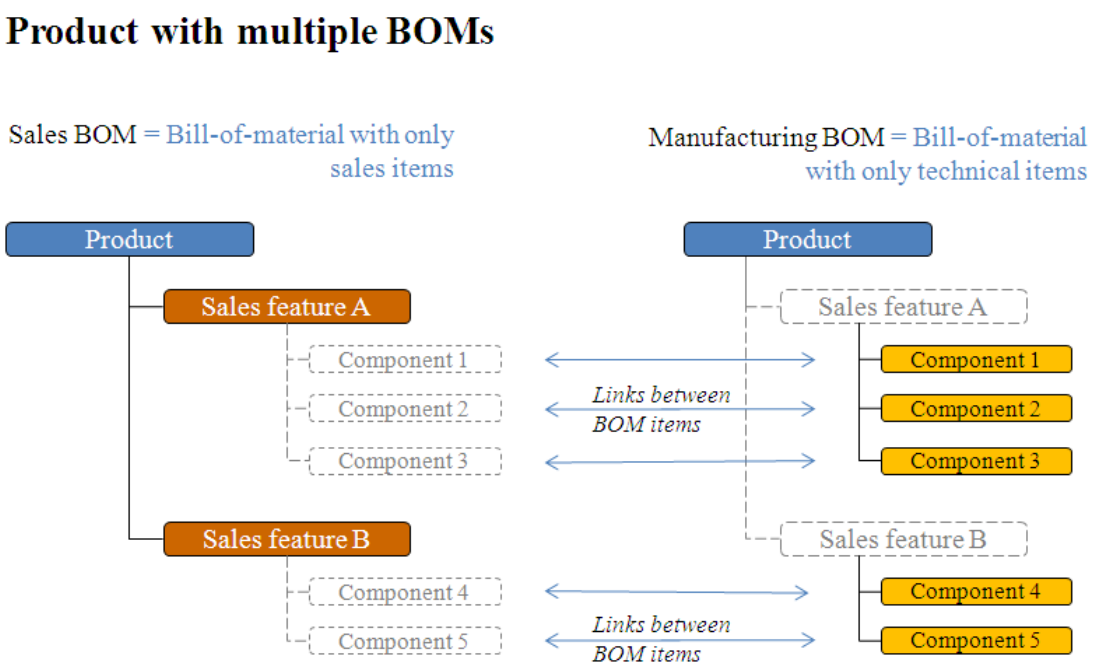

Figure 9 – Product modeled with multiple bill-of-materials: separate BOMs for sales and manufacturing, including linkages between the BOMs

Overall, both BOM modeling approaches are designed to provide (only) relevant configuration-related information to each user group. The selection between them is always case-dependent: in general, the single BOM approach suits to more simple products, while multiple BOMs should be used with more complex products. Further, even if the latter approach is theoretically stated to be suitable with the complex product cases, the real-life cases conducted by e.g. Tiihonen et al. (1996), Forza and Salvador (2001), and Hvam, Pape, and Nielsen (2006) have found that

many times companies are using the single BOM approach, regardless of the product complexity. As a result, the companies face challenges of overly technical and complex sales configuration requirements. In these cases, it was typical that the companies had realized the problem of this overly technical approach, but due to either lack of emphasis or suitable product modeling solutions, the situation had not been completely solved, even after employing a more sophisticated product configurator system. (Tiihonen et al., 1996; Hvam et al., 2006)

Differing requirements within a single sales view

In addition to the different requirements between sales and manufacturing views, it is many times the case that a single view itself needs to provide multiple viewpoints and levels of abstraction to the product item content. This is especially the case within the sales view, as it has varying user groups: the sales configurator is either directly used by customers, or by a company's sales person according to the specifications given by the customer. (Tiihonen, 1999) In both cases, the technical sophistication level of the user can vary highly: As companies have multiple customers, they also cover a wide range of technical expertise; some customers are only willing to receive a functioning entity, while others want to specify all the low-level technical details of a product. On the other hand, also the sales personnel vary in their product knowledge and expertise; less educated and not much technically-oriented sales persons naturally prefer more functional level sales configurator views as well, while more trained salesmen might frustrate for the overly abstract sales configuration level when trying to fulfill the needs of technically-oriented customers. (Leckner et al., 2003)

Both these factors affecting the suitable level of sales view abstraction are illustrated in Figure 10 below (adapted from multiple sources: e.g. Tiihonen, 1999; Leckner and Lacher, 2003). A mismatch between the sales configuration view abstraction and either the customer desires or the sales person capabilities is an unwanted situation from multiple perspectives: the customer either decides not to buy or ends up with a sub-optimal option. Neither one is naturally a desired state for the customer nor the seller. (Forza et al., 2002; Hvam et al., 2006) The problems are especially felt in cases of complex products with technically demanding solutions, as they require a

comprehensive understanding of the product. In these cases, it might not be possible to simplify the configuration for less-skilled users, not even through creating a separate, simplified and functional-level sales BOM. (Arana et al., 2007) As a result, the most feasible option in these cases can typically be the usage of technically skilled sales personnel or at least a team of sales support engineers who can assist less-skilled salesmen in the more complex cases. These personnel could then cover the support for all customer cases, regardless of their level of sophistication. (Tiihonen, 1999)

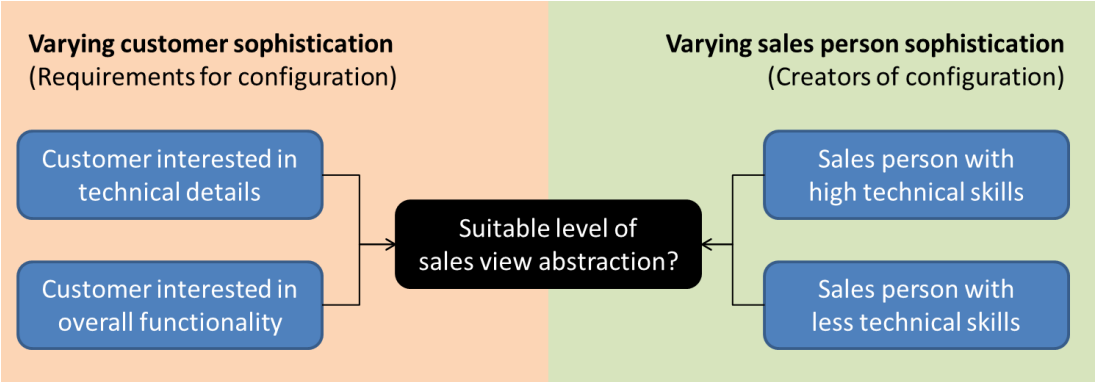

Figure 10 – Factors affecting the required abstraction level of the sales (configuration) view

2.3 Supportive IT infrastructure for product configuration

In addition to the previously discussed practicalities and needs of product configuration tasks, it is important to consider the role of product configurator as a software support tool which needs to be integrated to the corporate IT infrastructure. This subchapter examines the typical IT systems required for successful product configuration, including PDM and ERP, in addition to the product configurator itself. After a review of general roles of the mentioned systems in the configuration process, different approaches for linking product configurators into the IT infrastructure are discussed.

2.3.1 Integration between product configurator, PDM and ERP

Although product configurator is the centerpiece of the sales-to-delivery process, it is clear that it cannot function without proper interaction with other corporate IT systems. More specifically, as the configurator "only" acts as a conversion tool between customer requirements and producible item definitions, it does not either

store the item information and the product structures, nor does it manage the actual production using the configured item data. (Heiskala et al., 2009) These tasks are executed by other support tools, more specifically PDM (Product Data Management) and ERP (Enterprise Resource Planning) systems. (Arana et al., 2007) More specifically, the PDM software manages and stores the item data which is needed as product configurator input. (Tiihonen et al., 1997; Kropsu-Vehkaperä et al., 2009) In turn, after the configurator produces a technical item listing, this configurator output is used in the ERP system to control the actual production process: the ERP software manages the sales order contents by scheduling and executing the production phase. (Jardim-Gonçalves et al., 2007) These most important configuration related tasks performed by the three tools are illustrated in Figure 11 below (adapted from multiple sources: e.g. Tiihonen and Soininen, 1997; Arana et al., 2007).

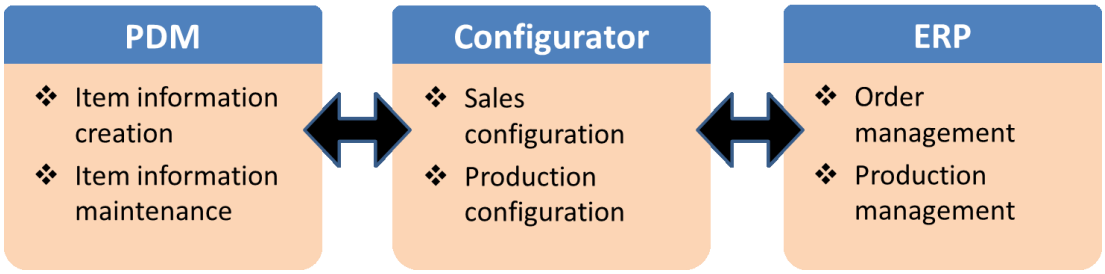

Figure 11 – Primary configuration-related tasks of configurator, PDM, and ERP systems

Further, the interaction between PDM, ERP, and the two product configurator modules (sales and production configurator) is more clearly visualized in Figure 12 below (adapted from multiple sources: e.g. Arana et al., 2007; Jardim-Gonçalves, Grilo, and Steiger-Garção, 2007). From the figure it can be seen that the PDM system stores both sales and technical items and BOMs consisting of them, and provides relevant parts of this information to both sales and production configurator tools. The sales configurator combines sales item information with customer requirements, and produces a listing of configured sales items, i.e. a configured sales BOM, which is typically used as a quote to be sent to customers. (Hvam et al., 2006; Sääksvuori et al., 2005) Then, the quote and the technical item information are used as inputs for the production configurator, while produces a configured technical (manufacturing) BOM. Thus, the sales order consisting of this technical item information can be sent to the ERP system, which controls the production process,

leading to a final product to be delivered to the customer. (Jardim-Gonçalves et al., 2007)

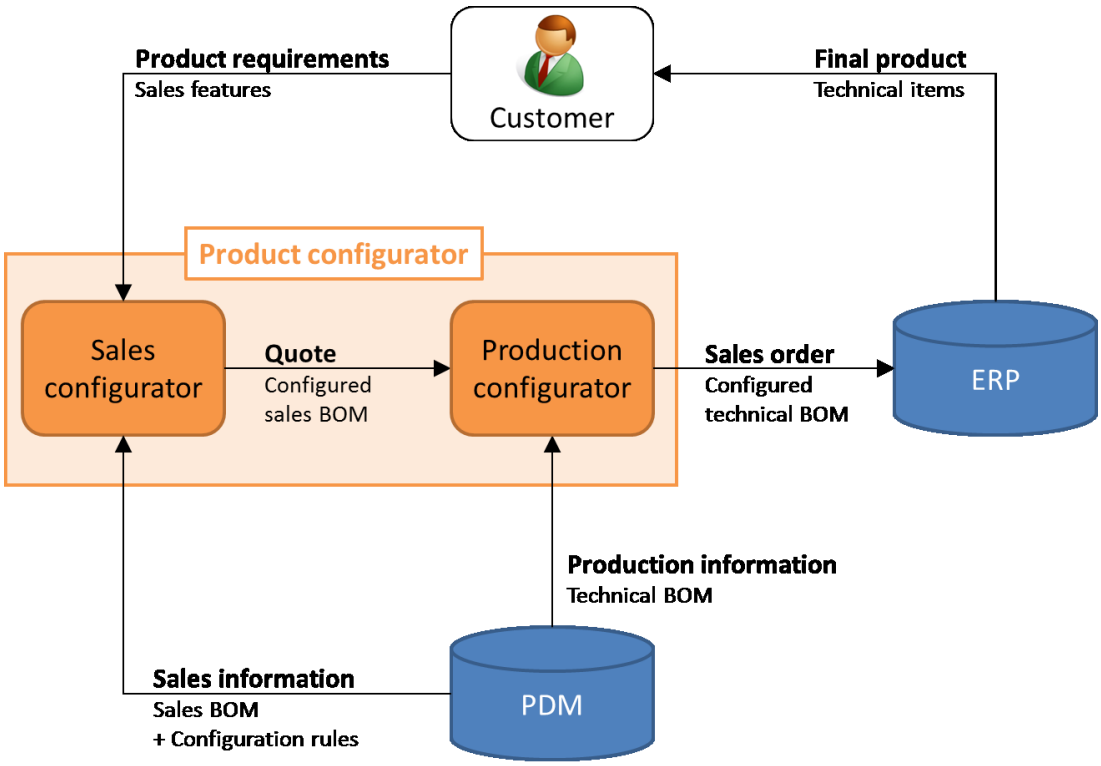

Figure 12 – Role of configurator, PDM and ERP systems in the corporate IT infrastructure

2.3.2 Approaches for linking product configurators to other IT systems

To ensure efficient usage of the data stored and managed in each of the discussed IT systems, the product configurator needs to be linked to each system. More specifically, it is important to study the linkage needs of sales and production configurators separately: typically, the production configurator is tightly linked to the ERP system (Gartner, 2011), as the item information used by this configurator module can then directly be used in the ERP system without further conversion processes. However, the sales configurator can either by an integrated ERP module or a stand-alone solution. (Forza et al., 2002) According to the case studies presented in the literature (e.g. Tiihonen et al., 1998; Arana et al., 2007) and Gartner's (2011) market reports, both these sales configurator alternatives are successfully used by

industrial companies. Thus, a comparison between the sales configurator implementations is presented in the following sections.

Sales configurator as an integrated ERP module

The approach of using an ERP module sales configurator does provide an undisputed benefit similar to the mentioned production configurator case: seamless integration of used item data. As there would be no need to build any customized interfaces between the ERP modules, the item data and order information management would be considerably streamlined. (Forza et al., 2002) On the other hand, there is one typical shortcoming with this approach: customizing the sales configurator functionalities to the company-specific needs is usually not feasible[1], as it leads to (costly) incompatibilities when the overall ERP system is upgraded to the next version. This customizability shortcoming might lead to difficulties in e.g. creating separate sales and production BOMs, as this integrated solution typically tends to be primarily linked to the technical BOM. (Arana et al., 2007) As a result, the ERP module sales configurators do not necessarily fit for more complex products with a need for abstract-level, overall functionality sales view: instead, the ERP configurator module solutions provide usually a good fit for offering standardized product range with relatively simple bill-of-materials and configurability needs. (Mesihovic et al., 2000) The general evaluation of this sales configurator type is presented in Figure 13 (adapted from multiple sources: e.g. Mesihovic and Malmqvist, 2000; Forza and Salvador, 2002) below.

Pros	Cons
❖ Seamless integration to ERP data ❖ No need to create additional, custom interfaces	❖ Limited customizability ❖ Possible difficulties in separating sales and production BOMs

Figure 13 – Evaluation of sales configurator implementation as an integrated ERP module

[1] Already in the beginning of 1970s, researchers such as Cheatham proposed that "in software, virtually anything is possible; however, few things are feasible." (Popek et al., 1981)

Sales configurator as a stand-alone solution

Based on the mentioned limitations of ERP module sales configurators, many companies have decided to apply specialized software solutions to support their unique configuration needs, such as extra calculations, user interfaces, and links to other systems in the configurator (Tiihonen et al., 1996; Forza and Salvador, 2001; Hvam, Pape, and Nielsen, 2006) The most important benefit from applying a stand-alone sales configurator is indeed the ability to somewhat easily (relatively inexpensively) customize the software exactly for the specific needs of the company's products: this ease and the cost-savings result from the typical possibility to tailor the software fully from the beginning, without strict base requirements of the standard ERP software. (Arana et al., 2007) On the other hand, the major shortcoming of employing a stand-alone sales configurator is the need to create additional, custom interfaces between the sales configurator and other IT systems, especially ERP and PDM: if the configurator cannot always receive up-to-date data from these systems, the efficiency of the configuration task decreases significantly. (Jardim-Gonçalves et al., 2007) The general evaluation of stand-alone sales configurator type is presented in Figure 14 below.

Pros	Cons
❖ High customizability ❖ Ability to tailor the solution from the beginning, no need to modify standard software	❖ Need to create custom interfaces to other IT systems ❖ Risk of using outdated ERP and PDM data

Figure 14 – Evaluation of sales configurator implementation as a stand-alone solution

Overall, both the solutions of ERP configurator module and a stand-alone configurator software have their own difficulties, leaving the decision of selecting an optimal implementation for a company to be made on a case-by-case basis: in some basic cases of very standard product offering, using a comprehensive ERP suite might be the best option, while in more complex product situations, creating a valid and complete configuration efficiently might only be possible with a company-specific solution. (Arana et al., 2007) However, as the landscape of corporate IT

infrastructure and factors relating to configuration needs in general (such as nature of the products and versatility of customer needs) are so multifaceted, it might not even be possible to show that some solution is explicitly better than other: the overall comparison depends on the criteria and company-specific emphasis given for separate categories. (Hovi, 2008; Gartner, 2011)

2.4 Special characteristics of system product sales configuration

Thus far the emphasis of this study has been on the configuration of single products. However, as the scope of this thesis is especially on selling and configuring complex system-natured products, this subchapter examines the special characteristics of system product configuration. First, the concepts of related to system complexity are clarified. Second, the general configuration differences between product and system businesses are studied. Third, a distinguishing characteristic of the system business, complexity of the configuration task, is examined. Fourth, the challenges of multi-level product offering, i.e. simultaneously selling singular and system products, are covered. Lastly, this subchapter discussed the methods for simplifying the complex configuration of system products.

2.4.1 Definition of product, system, and system complexity

As discussed, configurable products consist of predefined components which can be combined according to customer specifications. Further, it is common that a configurable product can be part of a larger entity, which bundles multiple products, and possibly also software and services. (Davies et al., 2007) These product bundles are sometimes called *system products*, as their description typically matches the basic definitions of a system, such as "a set of entities with relations between them" (Langefors, 1995). Conceptually, the difference between products and system requires the definition of a product. Although product's definition can be as wide as "anything produced", in the scope of this thesis, the difference is defined to rise from selling ability: the smallest entity, which is directly sold to customers by the manufacturer, is defined to be a product, while any entity combining multiple sellable products is called a system. These definitions arise from the scope of this thesis: sellable products can be specified separately with a sales configurator, making smaller components somewhat irrelevant from the configurator point of view. The

difference between configurable products and systems is illustrated in Figure 15 below (adapted from multiple sources: e.g. Tossavainen, 2002; Davies et al., 2007).

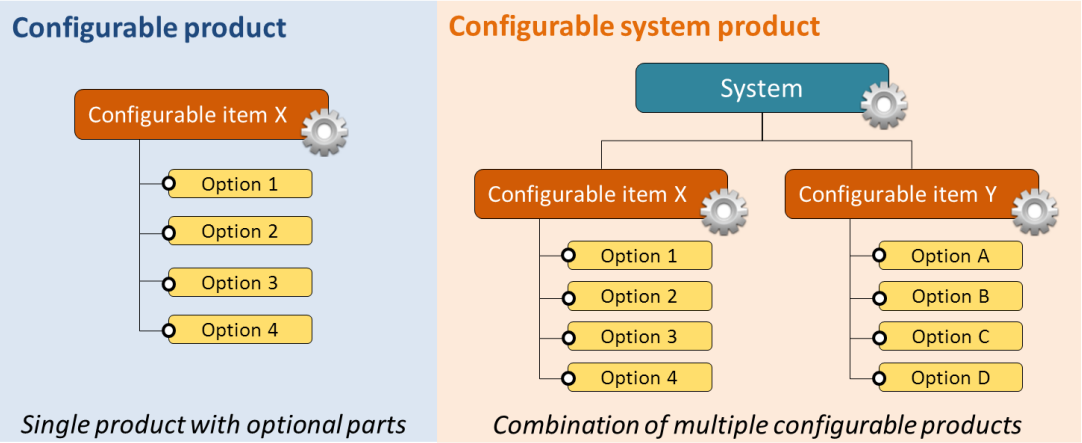

Figure 15 – Difference between configurable products and systems

In addition to product-system distinction, the term *system complexity* needs to be defined. This is done by separating the concepts of *large* and *complex* systems: typically, the term large is used to represent physical size (small / large), while the term complex relates to interactions between multiple parts (simple / complex). (Tossavainen, 2002) These differences are highlighted in Figure 16 below (adapted from multiple sources: e.g. Mattsson, 1973; Tossavainen, 2002). In this thesis, the emphasis is especially on complex, and not necessarily large, system products.

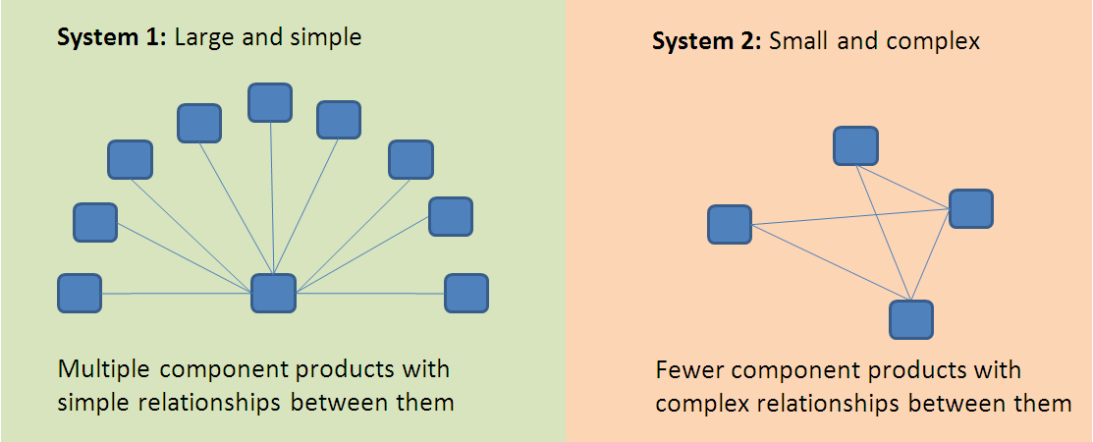

Figure 16 – Illustration of differences between large and complex systems

2.4.2 Complexity of system product configuration

From a configuration point of view, the distinction between products and systems is usually important, as it directly relates to the complexity of the configuration tasks. (Hvam et al., 2006) The configuration of a single product, such as a car engine, is typically somewhat straightforward, as the number of variables is limited. At the same time, the configuration of a system product might be significantly difficult, as it includes an additional dimension: for example, the configuration of a whole car (defined as system, based on the above definitions) might include both selecting the desired engine type and defining the desired variables among that engine. In addition, all the other products needed for a complete car, such as tires and a chassis, need to be defined similarly. As a result, the complexity of the car configuration rises dramatically, and the car selling process might become overly challenging to manage. This system configuration complexity is illustrated in Figure 17 below.

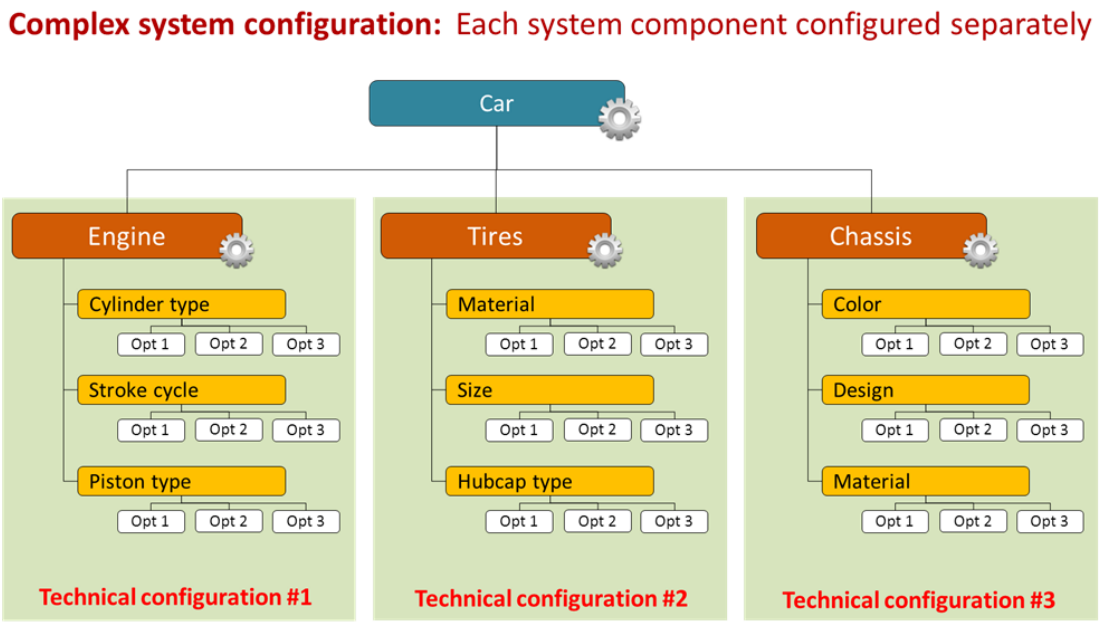

Figure 17 – Complex system (car) configuration with multiple technical-level component configurations

The complexity in the figure's car configuration example roots from the need to configure each car component as if they were sold separately, to e.g. a customer willing to only buy an engine. Of course, in real car sales, this is not the case: Normally, neither the customer nor the sales person is asked to define low-level technical details of single car components. Instead, as the customer is typically

interested only in the overall functionality of the car, the unnecessary details are hidden from the customer. (Davies et al., 2000) The resulting, simplified configuration task is presented in Figure 18 below: as the number of required option selections is decreased, the whole car can be configured at once. However, the product configuration research shows that in many real cases of somewhat complex products, companies are not able to provide this kind of simplified sales view for the customer, but instead support only a manufacturing view with overly technical options for the sales phase. In these cases, the companies offering difficult-to-configure systems are typically aware of the challenges in their offering, but due to e.g. inflexibility of information system capabilities, the situation cannot always be easily changed. (Tiihonen et al., 1996; Forza et al., 2001)

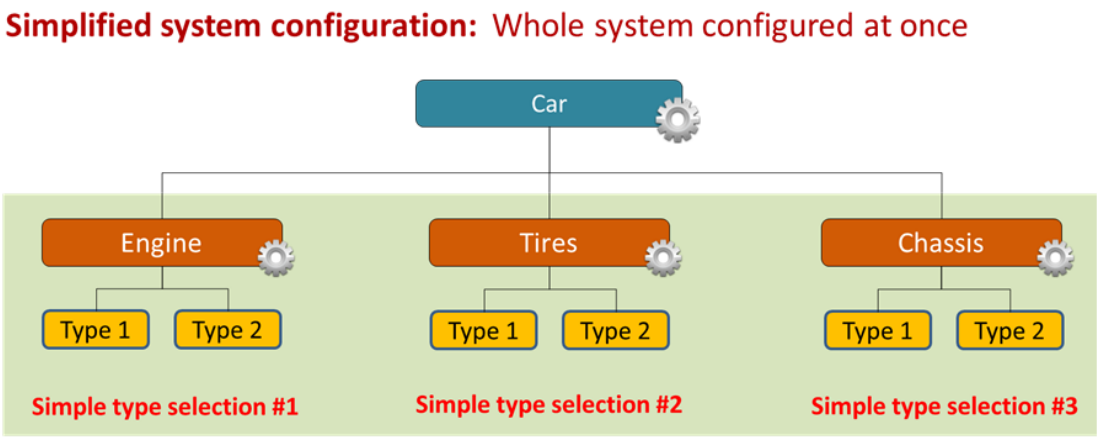

Figure 18 – Simplified system (car) configuration with component technical details hidden

Multi-level product offering and system configuration complexity

In addition to the general inflexibility of information systems, a major reason for the overly technical and complex system product configuration is the possible existence of *multi-level product offering*. The term describes a product portfolio in which sellable products are also used as part of larger entities (systems), thus creating sales opportunities in multiple offering levels. As a result, the management of offered products becomes considerably difficult (Huffman et al., 1998): If a company would offer only e.g. system products, it would be relatively straightforward to create simplified configurator views for the system sales needs. However, if a company is not only selling systems, but also the component products of the system, it is

significantly more likely that it runs into problems of complex system configuration. This argument is validated by e.g. Kropsu-Vehkaperä et al. (2011), who state that "the most difficult cases [for creating efficient configuration principles] are companies with two-level products, where sales item A is also a part of item B". A general illustration of this type of multi-level product offering with an additional offering level is presented in Figure 19 (adapted from multiple sources: e.g. Hobday, Davies, and Prencipe, 2005; Kropsu-Vehkaperä et al., 2011) below.

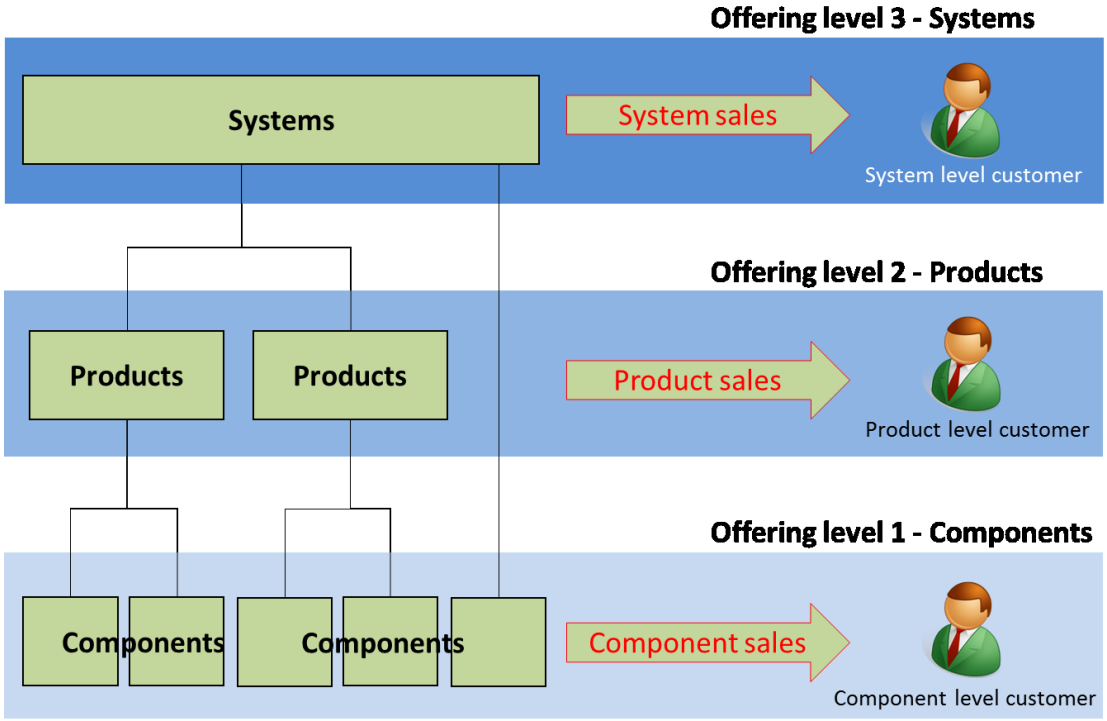

Figure 19 – Illustration of a multi-level product offering with component, product, and system sales opportunities

In the figure, company's product portfolio consists of three levels: component, product, and system sales. In other words, the company is offering each hierarchical part of a system: the system product itself, the system components, and the system subcomponents. In general, the difficulty of system configuration in the case of multi-level product offering results from a tendency to avoid redundancy: companies typically to try to utilize the existing configuration practices of the system's components to avoid unnecessarily duplicating configuration models. In other words, as the company has already created a configuration model and principles for defining e.g. a car engine, it is likely that this same engine configurator view is also exploited

when the engine is used as part of a car. (Hobday et al., 2005) Thus, the configuration of a whole system might require specifying each system component in a separate configuration view, thus making the overall process unnecessarily complex. This in turn easily leads to laborious configuration task (Leckner et al., 2003), erroneous configurations (Kropsu-Vehkaperä et al., 2011), and e.g. unnecessary variation, as there typically is multiple low-level combinations which would fulfill customer needs. (Tiihonen, 1999)

Multi-level product offering and different abstraction levels

As the consequences presented above can result from "only" two-level product offering, companies pursuing more highly hierarchical offering need to face even more difficult complexity related challenges. Although it is not particularly common to offer products in more than two levels, the rare cases are forced to solve these challenges in one way or another to prevent configuration requirements from becoming inhuman. The solution to the complexity challenge lies in the detail of customer needs: typically, a customer is interested in the overall functionality of the product, and possibly some details of the product's components. Thus, almost regardless of the offering level, the customer is not interested in the low-level details of the components, and especially not in the specifications of the subcomponents. As a result, a company should hide the uninteresting detail level from the customer and instead internally decide the most optimal and easiest-to-produce content for these low-level modules. (Hobday et al., 2005)

The varying customer interests per offering level are illustrated in Figure 20 below. The figure presents a (somewhat fictional) case in which a car manufacturer offers not only cars (system level), but also car components (product level), and even single parts of these components, thus pursuing a three-level product offering. As discussed above, the customer interest is in different issues in the business of each separate offering level: A car buyer does only care about the overall car entity, and some details of the engine, but certainly not about the details of the engine components; the low-level details can thus be defined by the manufacturer internally. Similarly, an engine buyer has high overall interest in the engine characteristics, and slightly on the engine component details. (Hobday et al., 2005) As the company has the freedom

to internally decide how to implement the layers not interesting to the customer, it is useful to standardize these self-decidable implementations. In the above car example, the manufacturer could predefine a few typical engine model alternatives to be selected into the car, and thus make the configuration process much more effective, both externally and internally. (Forza et al., 2006) This system component standardization approach is discussed further in the next subchapter.

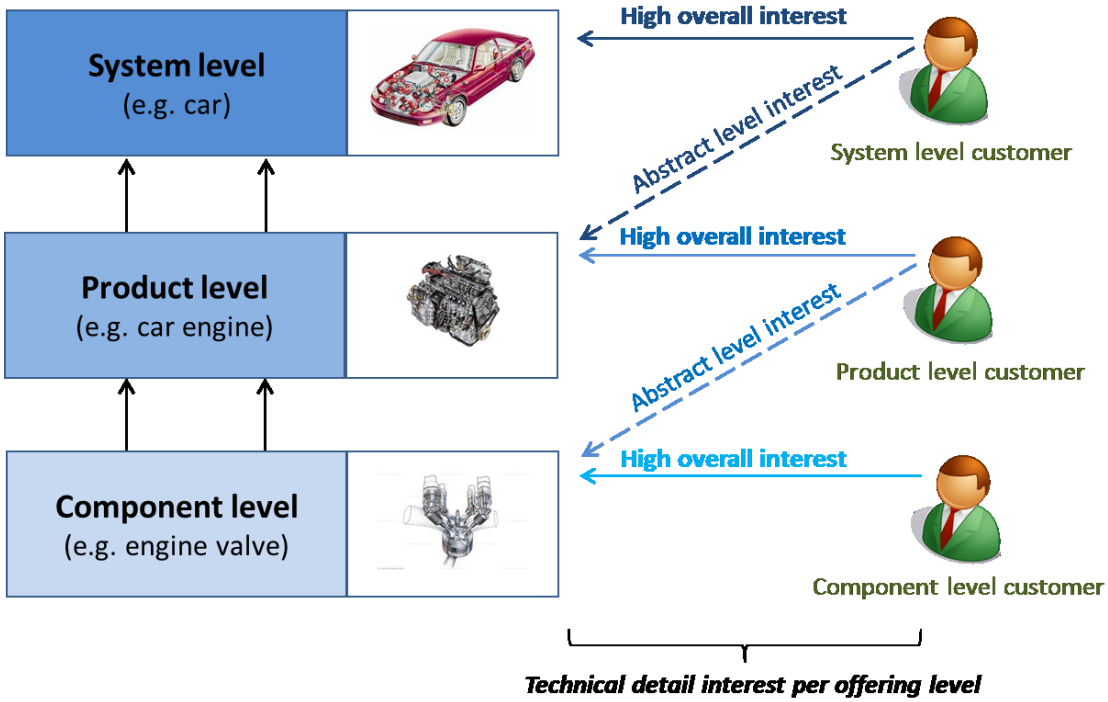

Figure 20 – Illustration of multi-level product offering of a car manufacturer and typical customer interest ranges per offering level

2.4.3 Methods for simplifying system configuration complexity

As stated, the configuration of system products might be considerably more complex than the one of singular products, as there are considerably more options to specify and relationships to manage. Thus, there is a clear need for methods to simplify this task: easily configurable systems require easy-to-configure structures. (Davies et al., 2007) One approach for easing the many-staged configuration process of systems is to create separate, more simplified configuration models for products when they are used as part of systems; however, based on the narrow literature on multi-level product sales, creating this type of simplifying masks over the product details for

system use are not commonly adopted. (Leckner et al., 2003) Instead, a somewhat similar approach of not only hiding, but more or less removing the need to select uninteresting components is used. In other words, the approach of specifying predefined and preconfigured component packages has been successfully used in some cases of the system sales literature. (Hobday et al., 2005)

Simplifying system configuration by productizing its components

In general, mass customization is based on the idea to use predefined components and group them into relevant modules, thus making the management and therefore the configuration of the product significantly easier and more efficient. (Pine, 1993) Thus, when aiming to mass-customize more complex system products, the same analogue is valid: if the variability range of system components can be clearly predefined and modularized, the benefits of mass customization and efficient product configuration can be similarly achieved. However, system business differs from traditional product business in a sense that the low-level details of the system components can be hidden from the customer, i.e. the system seller has more freedom to internally decide which components to use in the supplied system. Thus, in system business it is feasible to standardize the components of which specifications the customer does not care for. (Forza et al., 2006)

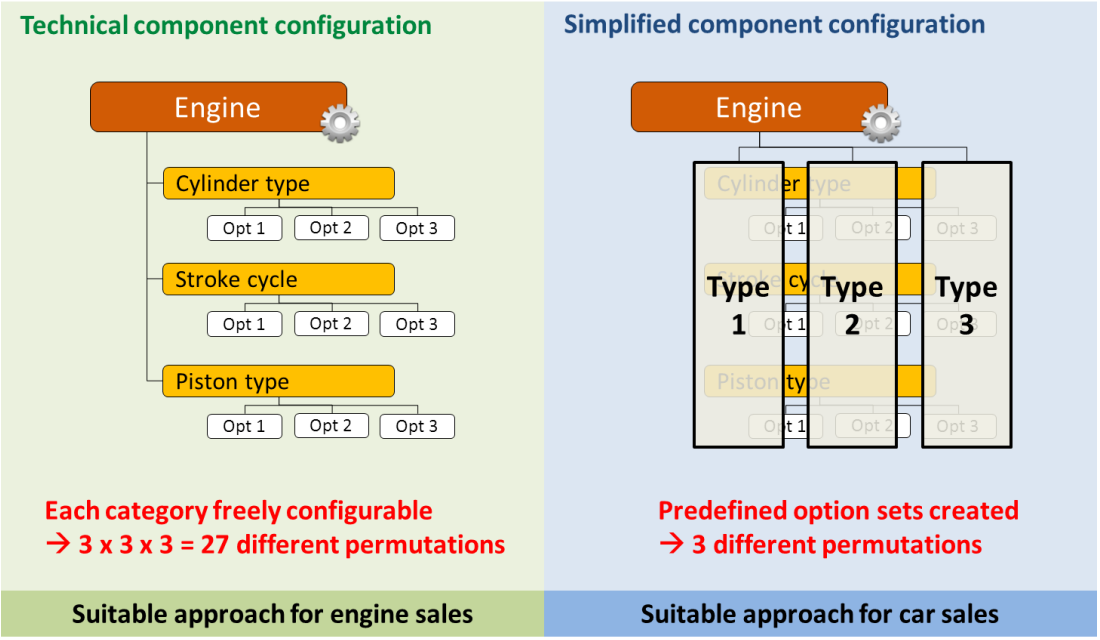

Figure 21 – Illustration of system component configuration complexity with freely configurable component options (left) and with standardized component combination sets (right)

The idea of system component standardization can be illustrated with the engine-car example (see Figure 21 above): if a car manufacturer predefined e.g. three typical engine alternatives (types 1-3 in the figure) for a car buyer to choose from, it is highly likely that the buyer is satisfied with at least one of the alternatives, as the engine is only one part of the whole car entity. As a result, the car configuration creation becomes significantly simplified, as the number of possible permutations narrows tremendously. However, for a customer buying only the engine, the predefined option package approach is typically too limiting, as the customer is specifically interested in the low-level engine details. (Hobday et al., 2005)

General consequences of component productization for system business

In general, it is important to note that in many cases, this kind of component standardization is not only a way to simplify the system configuration task, but also the key to success in system product business overall: less variability leads to easier manageability, which in turn reduces the "hassle" and enhances internal efficiency. (Davies et al., 2007) Further, as the system R&D emphasis can be targeted on only a limited number of standardized components, the company can also productize the linkages and connections between these system parts; thus, an additional competitive advantage for the system manufacturer can stem from making the system to be "more than the sum of its parts". (Parantainen, 2011)

Other system component productization benefits include e.g. ability to make predefined components into inventory and possibility to hide component prices by pricing only the option package itself. On the other hand, there naturally are also downsides with this component productization approach: e.g. customers have less ability to customize the component details, and companies might find it difficult to define which kind of option packages would best fit to majority of customer needs. In general, most of the benefits and challenges are somewhat identical to the corresponding issues of mass-customized products: although there are some major differences between system and product business, the general idea of creating a customer specific instance from predefined components can be applied in each level of corporate product offerings. (Hobday et al., 2005)

3 Benchmark case studies

To complement the previously presented literature review, three benchmark case studies were conducted. The aim of these studies was to understand how the configuration of complex system products is executed in these companies. This chapter reports the findings from these cases: First, a background subchapter denotes the criteria for company selection and configurator solution evaluation. Then, the rest of the chapter presents the three cases studies, including Benchmark Company 1, Benchmark Company 2, and Benchmark Company 3.

3.1 Background and motivation

This subchapter provides background information about the mission and execution of the conducted case studies. As the previously presented literature review provides an essential background for understanding the general challenges related to system product configuration, these case studies aim to complement this theoretical knowledge with practical insights from real-life corporate settings. The general target is to gain a more comprehensive understanding on how the system product configuration difficulties have been currently solved in real companies, especially in the sales phase: the emphasis is on the role of product configurator in the corporate IT infrastructure and the general benefits and challenges of each implementation type. In addition, the nature of each case company's business, products, and customers are identified, to enable easier comparison of the feasibility of the implementations and higher generalizability of the findings.

Complementing theoretical viewpoints with practical insights is considered to be highly beneficial in product configuration research in general (e.g. Tiihonen et al., 1996; Skjevdal and Idsoe, 2005), but according to Kropsu-Vehkaperä et al. (2011), especially important in the case of system products. In their study of Finnish ICT companies, the researchers found out that a major reason for current configuration (complexity) problems "is seen to lie in the companies lacking of benchmarking knowledge". They reasoned this shortcoming by stating that "managing [especially system product] configurations is seen as a competitive factor that companies are not willing to share". (Kropsu-Vehkaperä et al., 2011) Thus, gathering the system

configuration management knowledge from the case companies of this thesis provides a possibility to make an important contribution to this research area.

Table 1 – Selection criteria for benchmark companies

Company selection criteria	Criteria details
ICT industry	Company's products should combine hardware and software
Multi-level product offering	Company should pursue both product and system sales
Differing configurator types	Both stand-alone and ERP module configurator solutions should be found among the companies

As this thesis is conducted for a Finnish ICT company, the case companies were desired to operate in the same industry as well. More specifically, there were two selection criteria (illustrated in Table 1 above): (1) the company should sell both system products and system components (multi-level product offering) and (2) there should be different configurator implementations (both stand-alone and ERP module configurators) among the companies. These criteria were used because the company the thesis is conducted for (1) does pursue a multi-level product offering, and (2) has somewhat recently changed its stand-alone configurator to an ERP module solution. Based on these criteria, the companies selected for the benchmark studies were Benchmark Company 1, Benchmark Company 2, and Benchmark Company 3, each from the Finnish ICT industry and with at least two-level product offering (systems and products). The general characteristics of these companies are illustrated in Table 2 below. The benchmark cases are presented in the next subchapters, with the structure of brief company description, the role of product configurator in the IT infrastructure, nature of business, and general evaluation of the used system configuration implementation.

Table 2 – General characteristics of selected benchmark companies

Company	Industry	Revenue 2011
Benchmark Company 1	Electrical equipment	> 10 billion €
Benchmark Company 2	Cargo handling	< 10 billion €
Benchmark Company 3	Telecommunications	> 10 billion €

3.2 Case 1: Benchmark Company 1

The first benchmark case company was an electrical equipment provider Benchmark Company 1. Due to its large and diversified product portfolio, the company employed multiple different configurator tools and configuration practices. Thus, to provide a suitable case study, it was decided to concentrate on a single solution of the company's certain business unit. The specific business unit was selected due to the fact that the unit employed self-created stand-alone sales configurator software for offering almost all the products within that unit. In addition, the product offering of the business unit consisted of both systems and system components, thus fulfilling the predefined criteria.

3.2.1 Nature of business, customers, and system products

In general, the nature of the business of Benchmark Company 1's business unit was identified to be somewhat volatile and project-based: a typical system product was basically tailored separately for each customer, as there were numerous parameters to specify when defining the exact configuration of the system. The need for vast amount of parameters was said to be needed for fulfilling highly variable customer needs: previous system product standardization attempts to limit the permutation space (for internal efficiency needs) had typically not been desired by customers. As a result, the system product business was identified to be difficulty repeatable and project-oriented. The adopted philosophy in the case of these system products was mentioned to be "we should operate in a customer-friendly, and not only production-friendly, way". In relation to multi-level product offering, the unit offered not only the systems, but also the system components. However, the business of the component level was reported to be somewhat minor, and thus the sales configurator software had been created to primarily serve the needs of system business.

3.2.2 System product configuration process and practices

When analyzing Benchmark Company 1's configuration-related IT infrastructure, it was found that unlike in many cases in the literature, the sales and technical items were stored in different databases. The technical items were normally managed in a PDM system, but the sales items, which formed a sales BOM fully separated from

the technical items, were stored in a separate template library database. Regardless of the separate storage locations, this approach made the sales configuration phase somewhat easy and efficient, as there was no need to consider producible items in the sales phase when creating the sales quote. However, the separate databases led to significant problems in the following production configuration phase: there was no linkage between sales and technical items, and the specific technical solution needed to be decided "on the run" by the production engineers. This manual definition phase made the overall configuration process somewhat unsuitable for higher-volume production. However, after the production configuration had been created, the data could be sent to the ERP system for production management, and finally the delivery to customers. Benchmark Company 1's configuration process and the supporting IT infrastructure are presented in Figure 22 below.

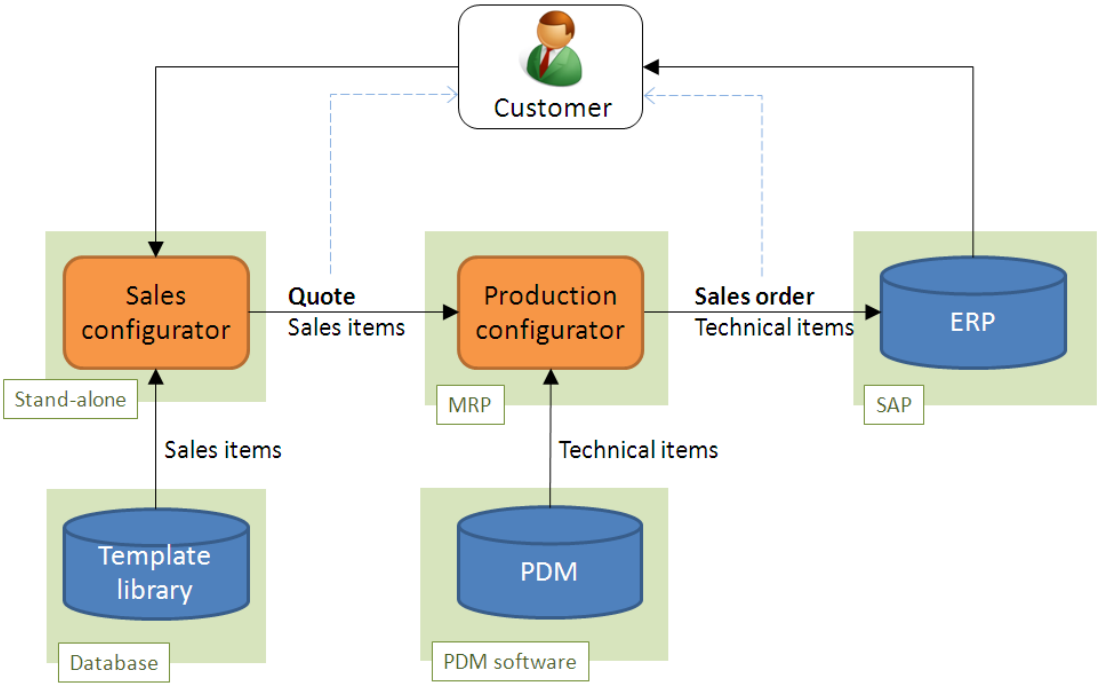

Figure 22 – The role of sales configurator in Benchmark Company 1's IT infrastructure

It can be seen from the figure that the sales configurator used was a stand-alone solution, and the production configurator was MRP system's module: more specifically, SAP's configurator module was not used, but instead the configurator module of the previous ERP system was still in use, being integrated to SAP. In general, the usage of separated sales items and a self-customized sales configurator

software led also to easy configuration rule creation: products' sales BOMs could be created directly by product managers, and no PDM expertise was needed. The stand-alone sales configurator also enabled its usage offline, as there were no direct linkages to PDM or ERP systems. Naturally, this approach also led to difficulties in keeping the item data up-to-date, as the communication between these systems required manual "push" inputs. The risk of out-of-date data and the fact that sales configurations were created in abstract level, without directly considering the specific technical solution, had led to the adaptation of considerable sales support teams. These technical support personnel checked majority of the system configurations manually, as otherwise there would have been a high risk of invalid specifications.

3.2.3 Evaluation of configuration process implementation

Pros	Cons
❖ Easy, fast, and flexible quote creation	❖ High risk of invalid configurations
❖ Sales features (not technical items) shown for customer	❖ Quotes not exact, manufacturing needs to engineer suitable solution
❖ Offline usage possibility	❖ Need for heavy sales support team
❖ Easy creation of configuration rules (no programming need)	❖ Data becomes easily out-of-date (sales configurator and PDM not linked)

Figure 23 – Pros and cons of the configurator implementation of Benchmark Company 1

The general strengths and weaknesses of the configuration practices of Benchmark Company 1 are presented in Figure 23 above. The most important pro is considered to be the fast and flexible sales configuration phase: as the sales configurator uses only feature-level product information, configuring a product does not require any further technical know-how. Other benefits include the customer-friendliness of being able to define only the functional level of the product, the mentioned offline usage possibility and the ease of creating the configuration templates without programming skills. Then, the most considerable shortcoming of the used approach

is the lack of linkage between sales and production specifications: the quote creation can be said to be done overly loosely, thus leading to a heavy sales engineering phase in the production configurator side, and a high risk of invalid configurations. In addition, as in offline and stand-alone implementations in general, there is no centralized control for keeping each configurator instance constantly up-to-date.

3.3 Case 2: Benchmark Company 2

The second benchmark case was conducted in engineering and service business group Benchmark Company 2, which serves a broad range of customers through e.g. its manufacturing know-how. Although the Finnish company is somewhat large with multiple business lines, it employed a single sales configurator solution for the majority of its offering, both in system and system component business. It was remarkable that the used stand-alone sales configurator software had been selected as a "best-of-breed" alternative among multiple sales configurator solutions: In 2008, Benchmark Company 2 had conducted a comprehensive comparing study of over 30 different solutions, including multiple vendors for both stand-alone and ERP module configurators. Particularly, the configurator solution needed to suit well for varying (multi-level) product offering needs of the company's respective businesses. As a result, the specific software was selected, since it provided high flexibility (e.g. ability to separate sales and manufacturing BOMs) and easy customizability (e.g. efficient logic rule creation with no requirements for programming skills).

3.3.1 Nature of business, customers, and system products

As mentioned, the business of Benchmark Company 2 takes place not only in system product level, but also in single product level. Although the product level business was not as significant as in system level, it was required that the configurator solution fully supported the product business needs as well. More importantly, it is notable that the company's manufacturing business is mostly engineer-to-order (ETO) based, although the components used were normally not designed from scratch; an example of a typically changing parameter was product height, which required "engineering" to extend the related components. Thus, the approach had also characteristics of make-to-order (MTO) supply chain strategies. Anyhow, as is typical in ETO and MTO environments, the customer needs varied on a case-by-case basis. Each product needed to be somehow adapted to customer requirements, but

mostly the changing parameters were related to physical dimensions, thus keeping the overall variability under control. Then, in relation to the nature of the system products themselves, the systems consisted of separately sellable components, thus requiring the configurator to provide multiple different abstraction levels to the same component, depending on the offering level in question.

3.3.2 System product configuration process and practices

This whole configuration process and the needed IT support systems of Benchmark Company 2 are illustrated in Figure 24 below. The sales configuration process started with visual selection wizard, from which a desired product type was selected. Each system product had a predefined sales template, i.e. functional level sales BOM with logic rules between the different BOM options. The sales configuration was made within the variability range of the template, thus creating an abstract level quote to be sent to customer ("as customer is buying functionalities, not technical items"). The configurator supported the sales person also by generating illustrative CAD drawings of the current configuration in real time for the user.

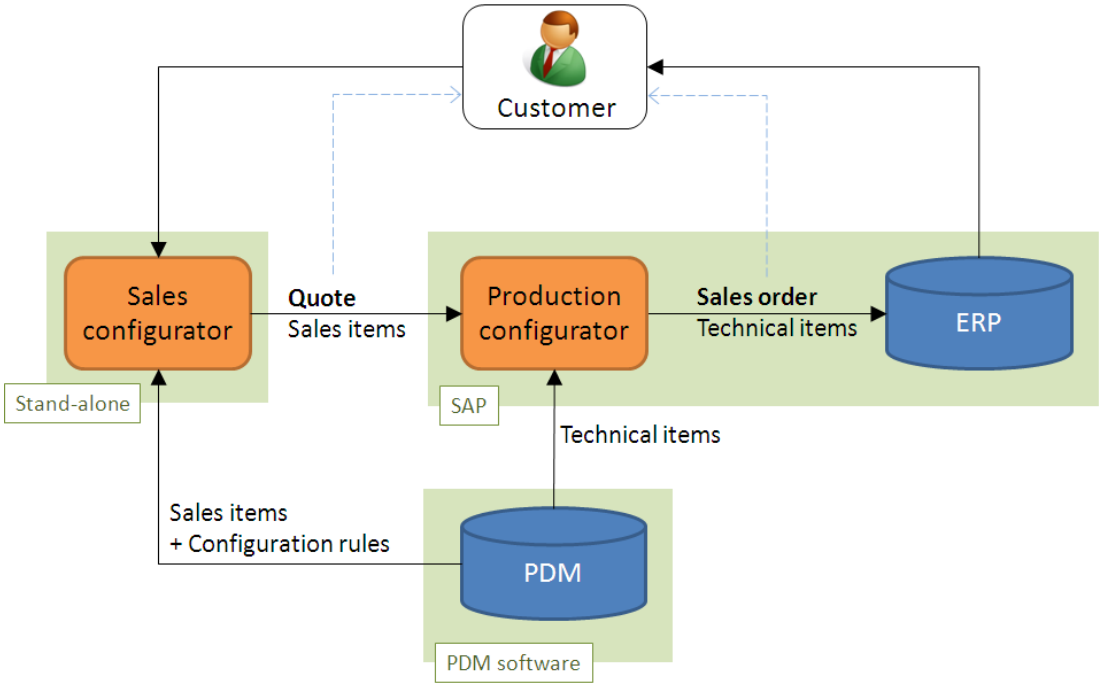

Figure 24 – The role of sales configurator in Benchmark Company 2's IT infrastructure

As can be seen from the above figure, the sales specification (quote) was also directly used as an input for the production configurator, which was the configurator

module of SAP. This conversion from sales features to technical items was executed in an exemplary way: the sales BOM had predefined linkages to producible technical items (also stored in PDM), and thus the conversion task could be automated. More specifically, a single, large production BOM entity was not needed with most system products: instead, only the separate linkages from sales BOM items to technical items were modeled. During the production configuration phase, a sales order acknowledgement was also created and sent to the customer: this document included more technical details than the previously sent quote, but did nonetheless hide part of the manufacturing print (actual sales order) content details. After customer received the acknowledgement, the actual sales order was inserted to the ERP system (SAP); finally, the items were produced, integrated and delivered to the customer.

3.3.3 Evaluation of configuration process implementation

Pros	Cons
❖ "Best-of-breed" configurator suits very well to company's needs ❖ High customizability & Easy configuration rule creation ❖ Easy-to-use interface with multiple optional views ❖ Separated sales and production BOMs, automatic linkages in between ❖ CAD drawings created on real-time based on configuration	❖ High investments costs likely required for configurator implementation and customization ❖ Heavy set of rules and interface maintenance needed

Figure 25 – Pros and cons of the configurator implementation of Benchmark Company 2

The general strengths and weaknesses of the Benchmark Company 2 case are presented in Figure 25 above. Overall, this case illustrated that a stand-alone sales configurator can be efficiently interfaced to ERP system, and most importantly, that the conversion from sales items to technical items can be successfully automated. Further, as the configurator software had been selected as the best option within 30+ alternatives, it was not surprising that it provided desired flexibility for both product

and system sales. In addition, the solution was highly customizable: Benchmark Company 2 was able to even provide different configurator user interfaces for different sales persons and sold product brands.

On the other hand, as always, there were also some downsides: as the sales configurator solution was largely customized to company-specific needs, it can be assumed that the investment costs required for achieving the tailored implementation were rather large. The issue was not discussed, but it is highly likely that this type of "best-of-breed" solution tends to be out of reach of companies with fewer resources to put on configuration management. In addition to the cost issue, another, somewhat minor shortcoming was identified to be the complex management of heavy set of configuration rules needed between the separated sales and production items; further, the configurator maintenance tasks in general were estimated to require the effort of 5-10 people. Overall, it is notable that outside the assumed high resource spending need, no major shortcomings were identified within the Benchmark Company 2' implementation.

3.4 Case 3: Benchmark Company 3

The third studied company was Benchmark Company 3 from telecommunications industry. The company's business consists of both overall solutions and equipment supplying, thus marking a need for a multi-level product offering. However, from the configuration point of view, the whole offering was covered with a single ERP configurator module solution (part of SAP). Thus, this benchmark case fulfilled the criteria of studying both stand-alone and ERP module configurators. Although the SAP configurator solution was used widely within the company, the benchmarking focused on certain type of system product business.

3.4.1 Nature of business, customers, and system products

In addition to the pursued multi-level product offering, the business of Benchmark Company 3 was identified to be largely project-based: it was rare that a customer would be willing to buy a standardized solution; instead, deliveries were tailored for the specific needs of each customer. Indeed, compared to the other two benchmark companies, the special characteristic of Benchmark Company 3's business was the technical sophistication of its customers: purely functional level sales specification

would not be enough for their customers, as the customers typically wanted to define the technical solution details by themselves. However, partly due to SAP sales configurator module's limitations on multi-level configurability, Benchmark Company 3 was able to build its offering from standardized components: within the configurable system structures, there were no embedded configurable product structures used; instead, the company had decided to create fixed, non-configurable items from the originally configurable product structures to be used as system components. The problem of this approach, the need to create multiple almost identical structures to match slightly varying customer needs, was clearly recognized, but it was considered the best option for the currently used, slightly constrained SAP sales configurator implementation.

3.4.2 System product configuration process and practices

The configuration process of Benchmark Company 3 differs from the other benchmark cases in a sense that the sales configurations were not created by sales personnel themselves, but by product experts familiar with the specific system product. This approach had been adopted because, as discussed, the nature of customers required already the sales specification to be somewhat technically detailed and customizable. As a result, the sales configuration was basically not at all done in an abstract level: instead, the configuration was directly done in a technical level. As the competence of sales personnel is typically limited in configuration cases requiring high technical knowledge, the decision to use product experts as the configurers was further validated. The sales configuration, which as a result acted also as the production configuration, was done within the boundaries of technical BOMs.

The system product structures and configuration rules were directly stored in the SAP configurator, and not in the PDM system which is the more typical approach. The PDM system included only the descriptions and BOMs of the individual (technical) sales items: these item data were combined as system product BOMs directly within the configurator. This combination was defined by the product expert, and implemented by a separate programmer, as typically is the case with somewhat technical user interfaces of ERP module configurators. The defined structure and

configuration rules helped the product experts to create valid configurations from the technical options. Thus, the quote creation phase did not typically require any further sales support personnel, as the configurers were experts themselves. The resulting technical quote was then sent to a separate, Excel-based pricing tool, which provided up-to-date costs and pricing data to complete the quote information. Then, the quote, which basically acted also as the sales order acknowledgement, was sent to the customer. After the quote was accepted, the rest of the process was executed straightly: the ERP system could directly use the ERP-based configuration data for manufacturing tasks. After the components had been integrated as a functioning system, the entity was delivered to the customer. The overall configuration process is illustrated in Figure 26 below.

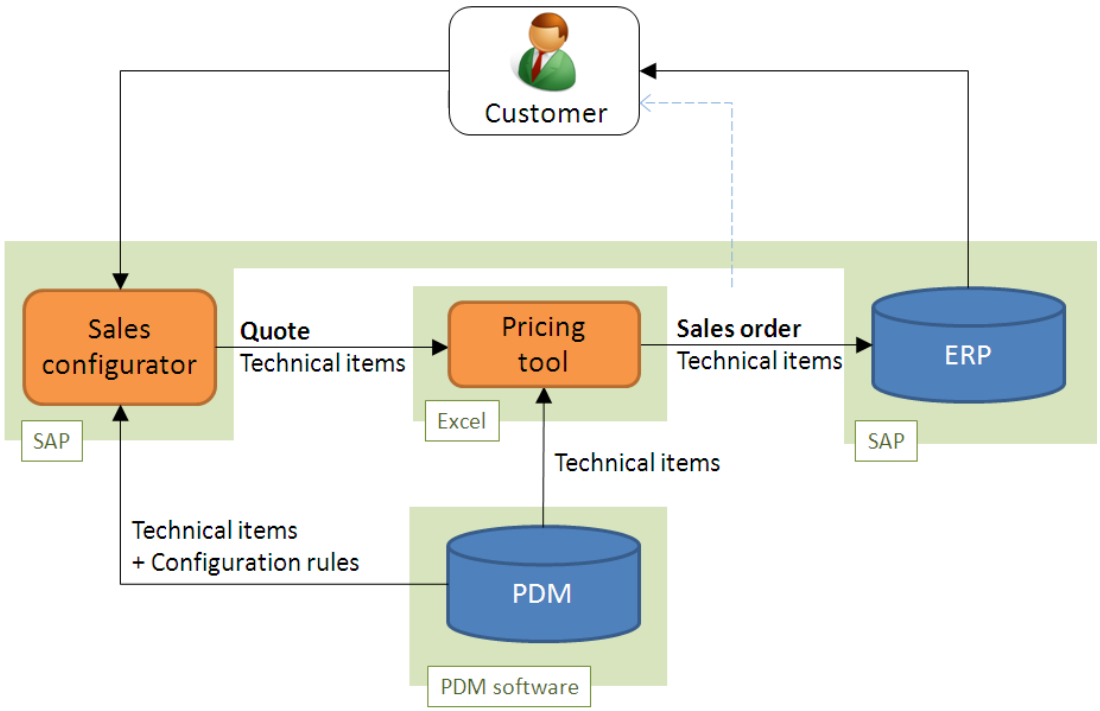

Figure 26 - The role of sales configurator in Benchmark Company 3's IT infrastructure

3.4.3 Evaluation of configuration process implementation

The evaluation of this benchmark case is presented in Figure 27 below. This case provided a good example of the usage of ERP configurator module. It was shown that the SAP configurator had some limitations in product modeling possibilities, which led to the need to remove configurability from the system component level

structures. However, the company had been able to manage this situation somewhat successfully: the decision to directly create technical sales configurations and use product experts to configure the systems showed to be a good fit for Benchmark Company 3's business needs. The conversion from sales to manufacturing was straightforward, and the risk of creating an invalid configuration was low due to these mentioned issues. In addition, as the company had created fixed configurations of its systems' components, the complexity of the structure management decreased significantly and the whole configuration process became more efficient.

Pros	Cons
❖ Technical items –based configuration can be directly transferred to ERP	❖ SAP configurator module does not fully support nested configurability
❖ Low risk of invalid configurations due to skilled sales configurers	❖ Product experts needed to create valid configurations
❖ Standard system components make configuration creation and maintenance easier	❖ Excel-based pricing tool does not enable automated sales process
❖ System structures can be create more freely in configurator than in PDM	❖ Standard system components do not allow much tailoring

Figure 27 – Pros and cons of the configurator implementation of Benchmark Company 3

On the other hand, the downsides of the overall configuration implementation were clear: most importantly, the SAP configurator did not provide the flexibility needed for more optimal system sales. Secondly, the need to use product experts in the role of sales configurers is typically not possible in companies with high sales volumes. Thirdly, as the quote needed to be manually exported to the Excel-based pricing tool, the otherwise seamless integration between the configurator and the ERP system did not enable fully automating the process. Finally, the approach of creating fixed sales items is always challenging, because the number of needed fixed configurations can easily explode, thus making item management considerably more difficult.

4 Summary of theoretical background

This chapter summarizes the findings from both literature review and benchmark case studies in a joint analysis. The target of this chapter is to provide a comprehensive overview of the most important issues related to the efficiency of system product sales configuration. These efficiency factors are summarized in the first subchapter, while the second subchapter provides a synthesis which identifies suitable actions which companies can take given their used sales configurator type. The synthesis framework is further used as the basis for extensive case company analysis in the following chapter.

4.1 Factors affecting system sales configuration efficiency

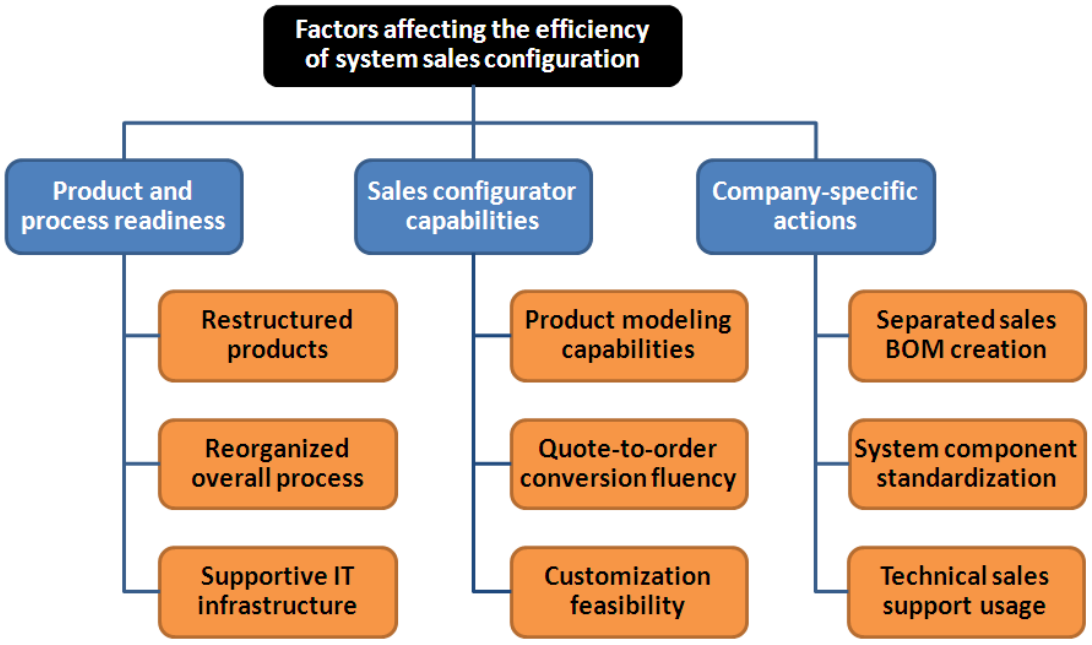

Figure 28 – Summary of factors affecting the success of system product sales configuration

Based on the findings of both the literature review and the benchmark case studies, three general factor groups affecting the system sales configuration efficiency were identified: (1) product and process readiness, which represent the fulfillment of general product configuration requirements, (2) sales configurator capabilities, which cover the analysis of configurator type selection consequences, and (3) additional company-specific actions, which can and should be taken in addition to the other two

general factors. The factors within these groups are presented in Figure 28 above, and discussed further in the following subchapters.

4.1.1 Efficiency factor 1: Product and process readiness

The most important general requirement for achieving efficient system product configuration process was identified to be the readiness of both company's products and processes for configuration (see Figure 28 above). First, modularizing products and creating configurable product structures to manage the modularity were considered to be crucial prerequisites for efficient product configuration and thus successful mass customization in general. (Tiihonen et al., 1997; Heiskala et al., 2009) The second prerequisite was found to be overall sales-to-delivery process realignment for configurator and general configurability needs: the process needs to support efficient creation of both sales and manufacturing specifications, and the explicit conversion between the phases. (Haag, 1998; Tiihonen et al., 1998)

Third, the need for IT infrastructure that supports system product configuration was identified: (1) the configurator modules need to be selected for matching the company-specific needs (Arana et al., 2007), and (2) the modules need to be properly interfaced with both PDM (storage of item data) and ERP systems (production process control). (Jardim-Gonçalves et al., 2007) The benchmark findings also underlined these issues: especially the case of Benchmark Company 2 proved to have successfully created easy-to-configure structures, automated the quote-to-order conversion process, and created fluent interaction between different IT systems.

4.1.2 Efficiency factor 2: Sales configurator capabilities

While the first efficiency factor related mostly on fulfilling the general requirements for system product configuration, the second factor focuses on the capabilities of the selected IT infrastructure, and especially the sales configurator functionalities (see Figure 28 above). Most importantly, it was identified that if the configurator can support flexible product modeling, such as the creation of separated sales BOM and (nested) configurability in multiple hierarchical levels, both the sales and production process phases can be enhanced significantly. (Arana et al., 2007) In addition, the efficiency of the process depends also largely on the fluency of the sales-to-production (quote-to-order) specification conversion: if the sales configurator only

supports manual conversion, the process cannot be automated and separate item insertion is needed. (Shamsuzzoha et al., 2011)

Further, if the separate sales BOM is used without full support for linking its sales items to corresponding technical items, the manual conversion phase might require even separated technical item definition. (Arana et al., 2007) Third, especially through the benchmark cases, it was also identified that the company-specific suitability of any sales configurator implementation depends largely on the feasibility of configurator customization: companies which had customized the sales configurator for their specific needs exhibited e.g. better system product modeling and process automation capabilities. Further, it was identified that stand-alone sales configurators were typically more customized (and thus pursued more capabilities) than ERP module alternatives, as ERP solutions were somewhat strictly linked to other ERP modules: changing one module would typically require changing also the others, thus making the single module customization less feasible than in the stand-alone cases, where the implementation can be more freely designed from the beginning. (Kropsu-Vehkaperä et al., 2011)

4.1.3 Efficiency factor 3: Company-specific actions

As the first two factors related to general configuration requirements and IT infrastructure solutions, there are also additional actions companies can take to enhance system product configuration (see Figure 28 above); these actions are not directly tied to product structures, process alignments or applied software implementations, but are more externally-natured and can be usually considered regardless of the specific product, process, or IT infrastructure setting. Overall, three external actions available for enhancing system configuration were identified:

(1) **Creation of separated sales BOM:** if supported by the used configurator, creating separate sales structures for products significantly simplifies quote creation. (Arana et al., 2007)
(2) **Standardization of system components:** through limiting product variety and predefining available component range, the process can be mostly automated and entity management becomes simpler. (Hobday et al., 2005)

(3) **Usage of technical sales support:** in cases of complex system products, sales configuration task might be considerably difficult for less-sophisticated sales personnel, thus leading to technical support need. (Tiihonen, 1999)

The existence of and differences between these factors were especially identified among the benchmark cases: successful implementations basically always included low component-level variety in systems, and either separated sales BOM creation (and thus simplified sales configuration) or usage of technical sales support personnel (as single BOM approach might lead to technical and complex sales views). The suitability of these actions for different sales configurator types are further discussed in the following synthesis subchapter.

4.2 Synthesis framework of theoretical findings

As discussed in the previous subchapter, there are three separate factors groups that affect the efficiency of system sales configuration. This subchapter aims to identify the theoretical part's most important takeaways for companies willing to enhance their system product sales configuration process. The coverage can be divided into two areas: (1) selection of the sales configurator type and (2) adaptation of suitable actions for that type selection (presented in the previous subchapter 4.1.3). First, there were identified to be two distinctive sales configurator types: stand-alone and ERP module. It was found that as stand-alone configurators are typically more feasible to customize, they can thus be developed to match company-specific needs for e.g. system product modeling and quote-to-order process automation. Especially, the stand-alone sales configurators were consequently found to typically support modeling system products with multiple BOMs; thus, as the sales configuration phase can be clearly simplified, the stand-alone alternative can be concluded to be typically better fit for system product configuration needs, especially in case of somewhat complex products. These sales configurator alternatives and system configuration enhancing actions that specifically suit each alternative are presented in a synthesis framework (Figure 29) below.

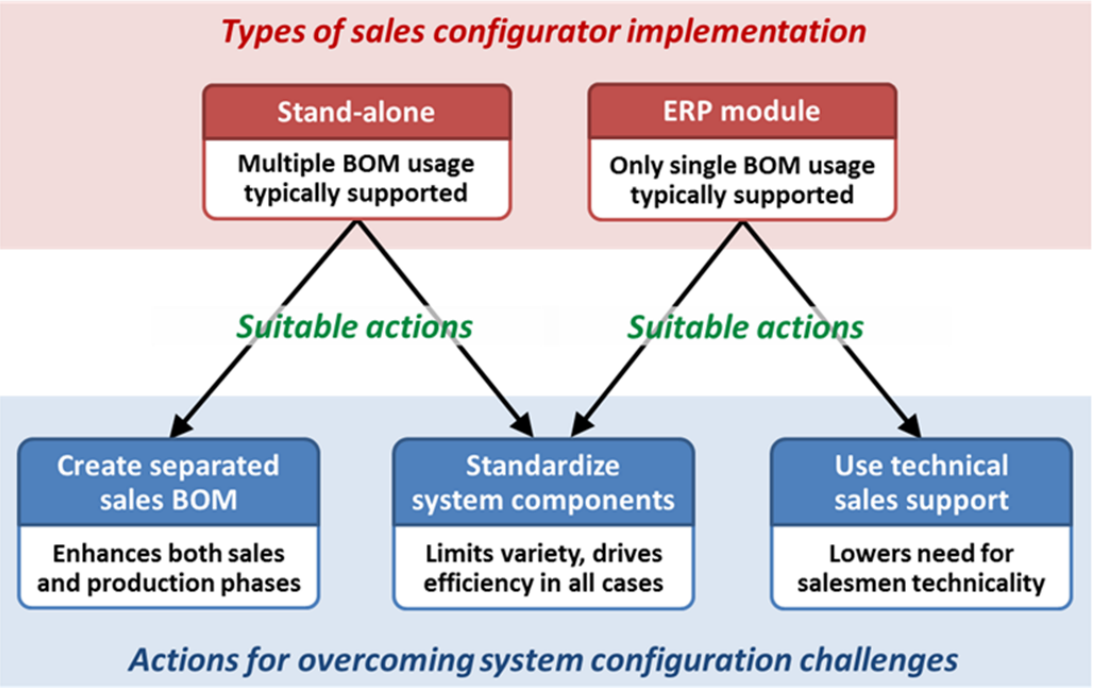

Figure 29 – Synthesis framework: typically suitable actions to overcome system sales configuration challenges for both sales configurator types

When identifying the suitable actions (marked in blue in the above figure) for each sales configurator type (red), it was clear that as stand-alone sales configurator tends to support multiple BOMs, the separated sales BOM should indeed be created, as it enhance both sales and production phases. However, successful system configuration can also be achieved with ERP module sales configurators: in these cases, only single BOM (which needs to simultaneously fulfill both sales and production needs) product modeling is typically supported, leading to technical and complex configuration task; as simplifying sales items cannot be used, the configuration task can anyway be managed by adopting a considerable technical sales support team to help quote creation and ensure the validity of these specifications. Finally, it was identified that both sales configurator type cases benefit vastly from precise system component standardization: if the component variability can be limited, the entity management becomes significantly easier and higher process efficiency can be consequently achieved.

5 Extensive Case Company study

This chapter provides an extensive case study of the system product configuration practices and challenges faced by Case Company from the Finnish ICT industry. After a brief introduction to the company, the current configuration problems and their causes are presented. Then, currently available alternatives for system product configuration are discussed in more detail, and evaluated along the different sales-to-delivery process phases. The evaluation is finalized by identifying the most suitable offering groups for each available modeling alternative. The main target of this chapter is to provide recommendations for the company on how should the configuration of system products be executed in the future, given the current IT infrastructure and nature of company's business and system products. These short-term action suggestions are further complemented with more general discussion for the long-term future considerations.

5.1 Background: Environment for product configuration

This subchapter provides an introduction to the Case Company and its environment for system product configuration. After a brief company description, the used IT infrastructure for configuration is presented. In addition, Case Company's current configuration practices are evaluated based on the theoretical framework established in the previous chapter.

5.1.1 Company description and product offering visualization

Case Company is a Finnish ICT company, which provides both products and services for its customers. It has operations in multiple countries within various customer segments. The product offering of the Case Company is considerably wide: it ranges from small singular products and single system products to more comprehensive overall solutions. It is typical for Case Company to utilize and cross-use separately sellable products also as components of the larger system entities. Thus, the product offering can be described as multi-leveled and hierarchical: Case Company has business in products, systems (combining many products), and bundled systems (overall solutions which combine products and systems). This layered offering is visualized in Figure 30 below with examples of typical customer groups. The

challenges this type of offering poses for system product configuration are further discussed in subchapter 2.4.2.

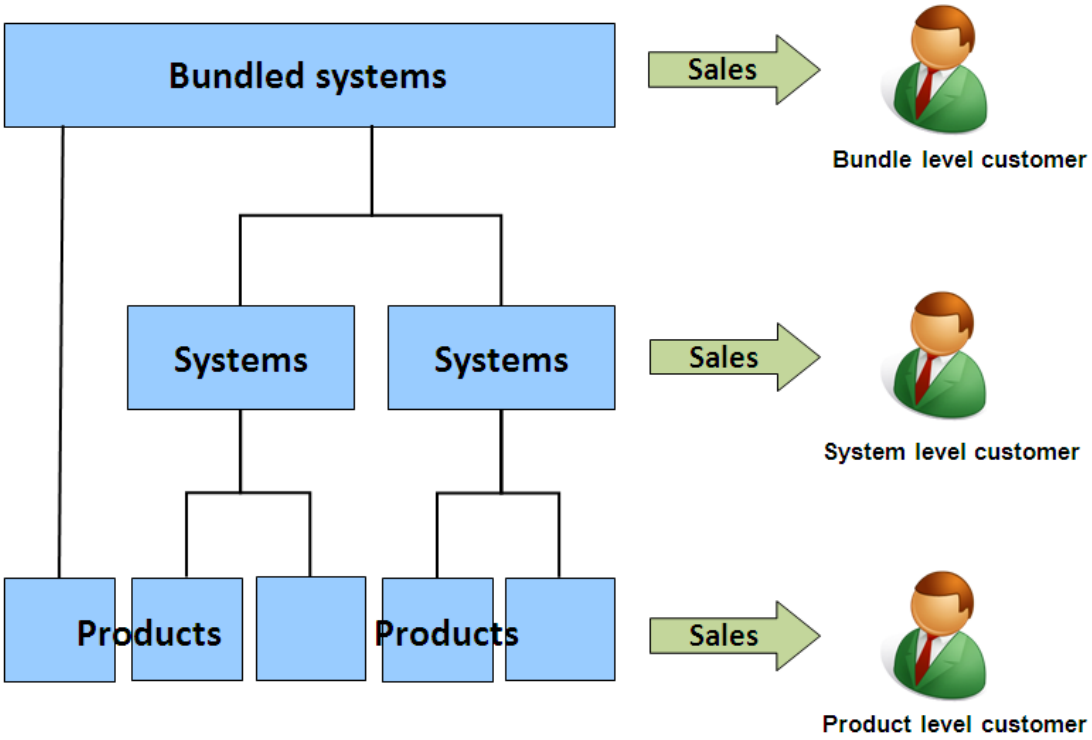

Figure 30 – Illustration of Case Company's multi-level product offering with typical customer groups

5.1.2 IT infrastructure for system product configuration

As was identified in the theory part findings, achieving successful configuration process requires adaptation of product configurator, including its both sales and production configurator modules, and interfacing it with other configuration-related IT systems, PDM and ERP. More specifically, the interfacing need was found to be dependent on the specific sales configurator type: either stand-alone or ERP module. In Case Company's case, the used sales configurator was an ERP module solution: in particular, both sales and production configurators were integrated modules of the used ERP system, Oracle's E-Business Suite. The ERP-based sales configurator solution had been somewhat lately applied in the company, as the previously used MS Excel –based sales configurator tool had been replaced in the year 2010. In addition to Oracle's ERP system and its modules, the only other configuration-related IT tool used was an external PDM system. Thus, in general level, Case

Company's IT infrastructure for configuration consisted of two parts, PDM and ERP, as illustrated in Figure 31 below.

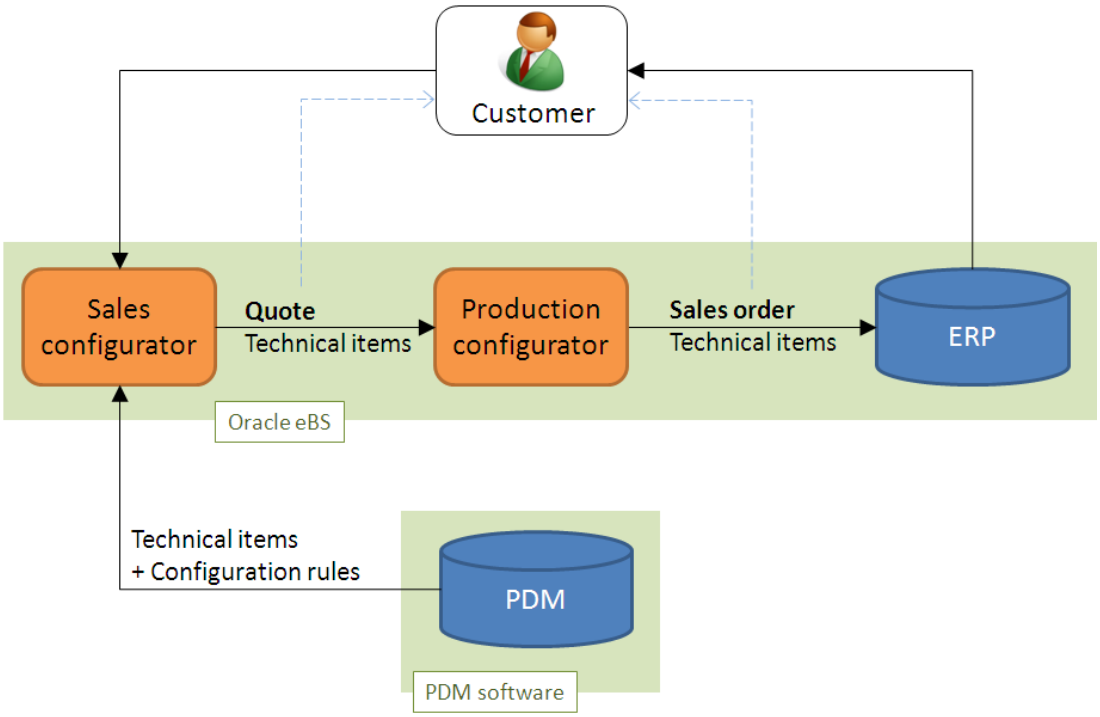

Figure 31 – The role of sales and production configurators in Case Company's IT infrastructure

As can be seen from the above figure, the sales and production configurators were modules of the same ERP system. Thus, the data used in each of the three ERP-including phases were seamlessly integrated, which had been one of the major targets of the ERP module configurator implementation. However, as the customization of ERP module sales configurators tends not to be particularly feasible (see subchapter 4.2), also Case Company's configurator had not been especially customized for company-specific needs: as a result, it currently had significant product modeling challenges, including the inability to clearly separate sales and production BOMs, and the limitation of using configurable components only in one hierarchical level (nested configurability disabled). Thus, the system products needed to be modeled with single technical BOMs without any configurable components, which in turn led to sales configuration (i.e. quote) creation with directly technical items. In addition, the production configurator input consisted of technical items: basically no separate quote-to-order conversion was needed, and the main functionality of the production

configurator was to check the validity of the items and provide general order information to the order.

5.1.3 Suitability to established theoretical framework

As was identified in the theoretical summary chapter (see Figure 29 in page 53), there are certain actions that typically suit for different sales configurator types. In Case Company's situation, the sales configurator is an integrated ERP module: for these cases, the established framework suggests actions of (1) standardizing system components, and (2) using technical sales support for making system product sales configuration more efficient. More specifically, the framework's suggestions were based on the argument that ERP module configurators do not typically support modeling system products with multiple bill-of-materials (to be separately used by sales and manufacturing): instead, only a single system product structure which should simultaneously serve both sales and manufacturing needs is usually used. The same limitation was also present in Case Company: system products were modeled with a single BOM. Thus, the framework suggested the two mentioned actions to overcome the technicality difficulties of this single BOM approach, which are presented in Figure 32 below: the stand-alone configurator related framework branch is dimmed in the figure, as they are not applicable for this specific company case.

The usage of the theory-based enhancement actions in Case Company is evaluated as follows: First, although the company had in some cases proposed a narrowed configurability range of its systems' components, it was common to allow the whole configurability range to be selected. Even worse, there were cases without any proper boundaries which component configurations fit with other system components. Second, according to the framework, the single BOM rooted sales configuration complexity should also be remedied with proper technical sales support personnel; however, Case Company only had a limited amount of these support roles in place for system products, as can be seen from the figure below. Overall, it was identified that Case Company has considerable room for improvement in the usage of these theory-based actions. This development need is further discussed in a subchapter (5.4.2) for long-term recommendations.

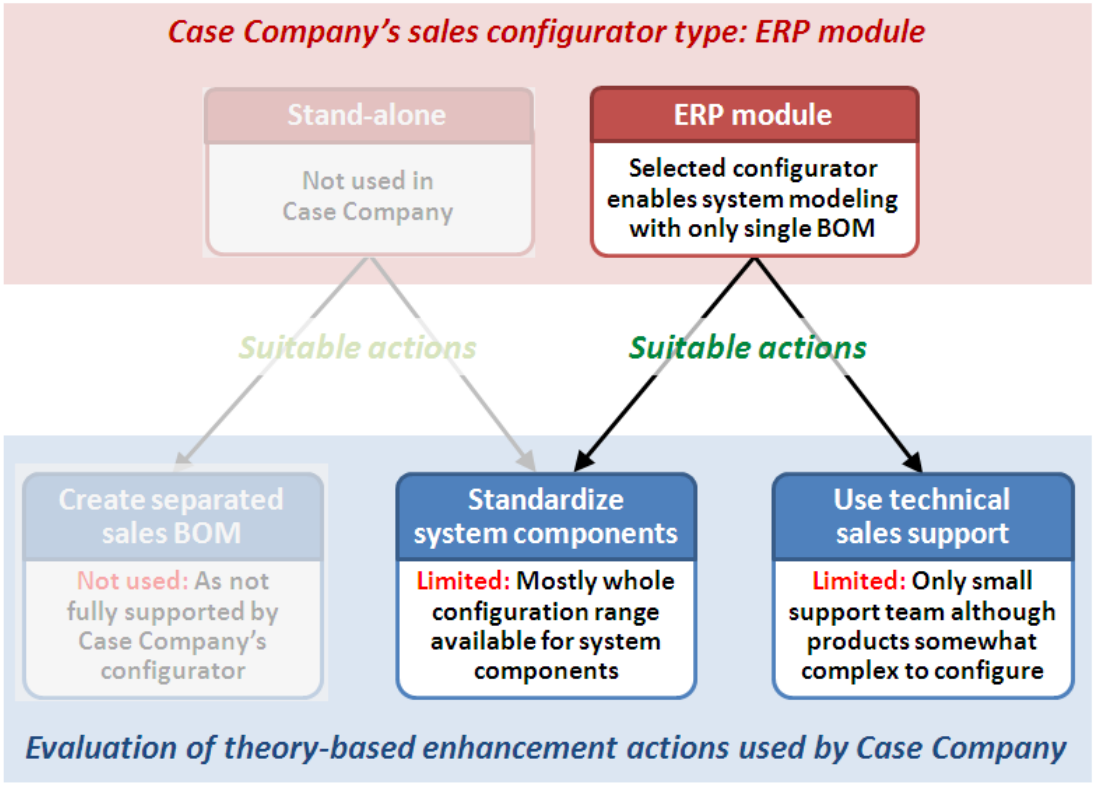

Figure 32 – Evaluation of system product sales configuration enhancement actions used by Case Company, based on the previously presented theoretical framework

5.2 Problem description: Inefficient sales configuration of systems

This subchapter presents the sales configuration related problem Case Company is experiencing, and discusses its main causes. The major challenge faced by Case Company is inefficiency in configuring and quoting its system products. It has been identified that the sales configuration (i.e. quote creation) of system products is difficult, complex, and time-consuming: the quote needs to be created by configuring each system component separately, and in the same technical level than if each component would be sold alone. This situation poses challenging requirements for the sales configurer, who should be able to master technical definitions of numerous component products and understand the specifications of the system entity as a whole as well. The requirements have not been easy to fulfill, and have thus lead to a high risk of invalid configurations and in general, low overall efficiency. Although the existence of this problem has been clearly identified in Case Company, there are certain reasons which hinder solving the problem in a straightforward manner. These causes for difficult quote creation, including the limited capabilities of the used sales

configurator and the challenges of varying product offering, are presented in the subchapters below.

5.2.1 Cause 1: Limited capabilities of ERP module sales configurator

When investigating the quote creation challenges of Case Company more specifically, it was found that a large portion of the problem is rooted on the currently[2] limited capabilities of the used ERP module sales configurator: as discussed above, Case Company's configurator lacked full support for separating sales and production BOMs, as was found to be a typical limitation for ERP module configurators in the theory part of this thesis. Similarly, the configurator lacked support for nested configurability, i.e. using configurable products inside larger configurable products (systems). As a result, system products and their respective sales quotes needed to be modeled as a list of separate configurable system components, as illustrated in Figure 33 below.

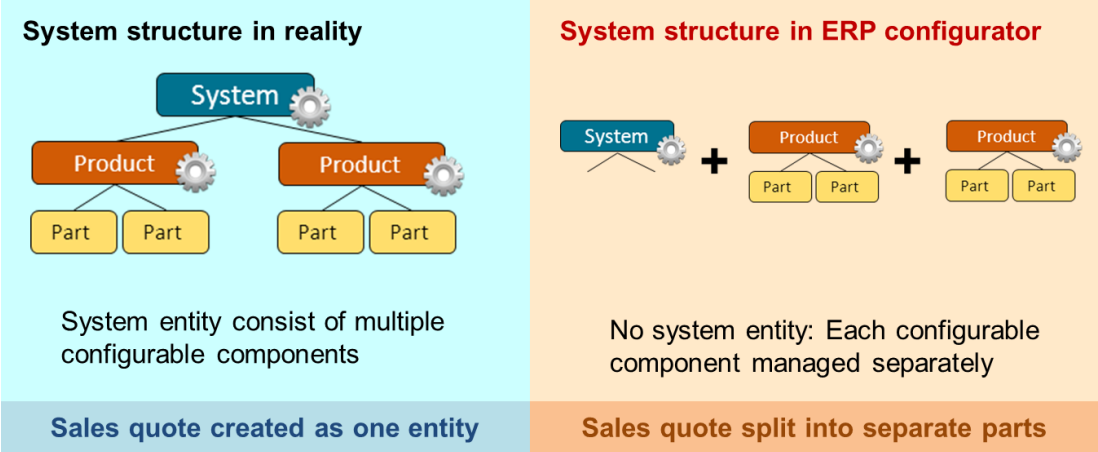

Figure 33 – Illustration of ERP module configurator's system product modeling limitations

As can be seen from the above figure, the ERP module sales configurator could process only one configurable structure at a time, leading to split quotes. This separation was problematic because each of these structures needed to be configured separately from scratch, i.e. in the same technical level as if they were sold alone. In addition, due to the separation, no validity checking or other interaction rules

[2] When this study was conducted, it was unclear if the present limitations of the sales configurator could be overcome in the future: even in the best case, the implementation of new functionalities would take over a year. Thus, this study focused on the present functionalities of the sales configurator.

between the structures could not be used, thus making it difficult to make separated system components fit together.[3]

5.2.2 Cause 2: Lack of system component configuration simplification

In addition to the system product modeling limitations, Case Company's system sales configuration challenges included also issues related to the company's highly varying and multi-leveled product offering (see Figure 30 in page 55): Case Company sold products in three levels (products, systems, and bundled systems), and cross-used lower level components widely in higher offering levels. However, from sales configuration point of view, selling same components in multiple levels poses a significant challenge for the provided level of abstraction: customer buying a large system is not interested in the low-level technical details of single system components, while a product customer typically needs the freedom to define each subcomponent detail. In addition, there might also be varying customer abstraction needs within a single offering level or even a single system: one system customer might require low-level detail definition, while another is only interested in a high-level entity.

As a result of this offering level and customer need variance, Case Company would need to be able to provide multiple sales configuration views for a single product, depending on whether it is sold directly for customers (technical details freely configurable) or as part of a larger system (limited detail variability enough). However, in Case Company's current configuration setting, only single configuration view per product was used. Thus, the technical details of system component could not be hidden from the sales person creating a system sales quote: as a result, the sales person needed to define components' low-level technical options which were not at all relevant for the system customer. This overly wide permutation range for systems' components led to overly technically demanding (and thus risky) and inefficient sales configuration tasks. The differences between Case Company's current, technical system component configuration approach and the simplified, likely more feasible alternative are presented in Figure 34 below. However, as Case

[3] Despite the mentioned system product modeling limitations, Oracle's configurator solutions (E-Business Suite and Siebel) were the only applications among Gartner's product configuration application suite comparison of top 14 vendors to receive the rating "strong positive". (Gartner, 2011)

Company had identified this problem, a few approaches had been planned to overcome both the challenges of complex system component configuration and the nested configurability limitation. These approaches are further discussed in the next subchapter.

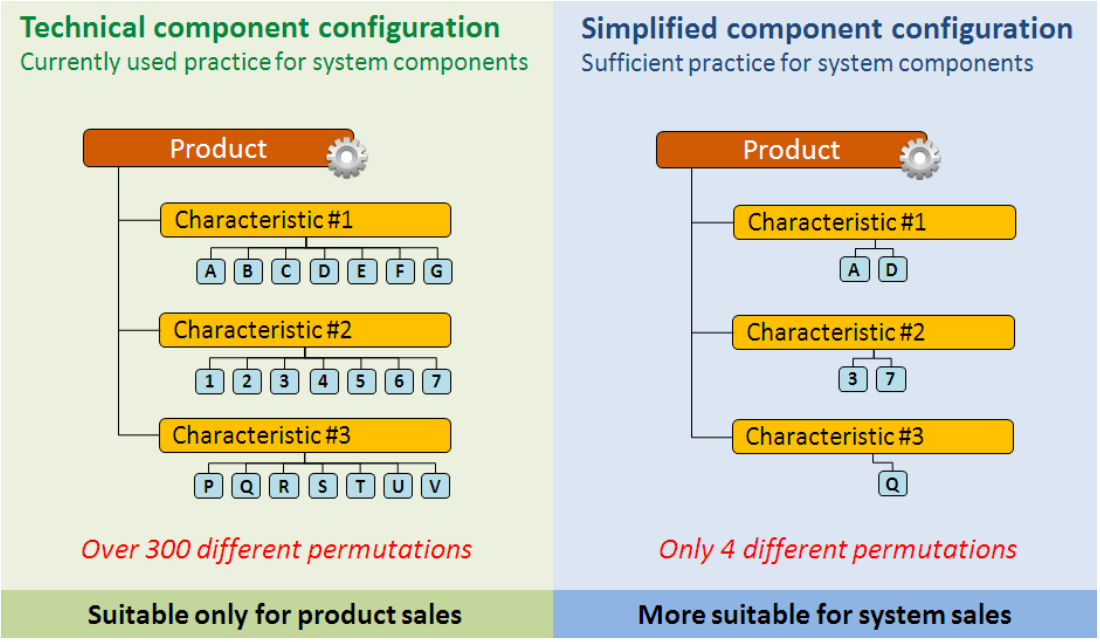

Figure 34 – Differences between Case Company's current and more simplified system component sales configuration alternative

5.3 Solution approaches: Enhancements in current environment

This subchapter presents the currently available solution approaches for Case Company's system product configuration inefficiency problem. First, these approaches are introduced in general, and second, their pros and cons are evaluated within the phases of the whole configuration process. Finally, the suitability of each approach for different product offering groups is discussed.

5.3.1 Suitable workarounds for current system configuration challenge

As discussed in the problem description subchapter, there are certain reasons why the difficult quote creation phase of Case Company's system products cannot be easily enhanced. As there reasons are related to the selected sales configurator software and the pursued product offering, changing these general boundaries is not a short-term task. In addition, the configuration enhancing actions recommended by the

established theoretical framework (better system component standardization and wider usage of technical sales support) are also somewhat longer-term issues. However, as Case Company cannot afford to wait years for larger scale changes which would affect these present shortcomings, there is a considerable need for more quickly implementable short-term solutions. When identifying the possible short-term approaches, it was recognized the sales configurator permits certain workarounds to its current limitations on system product modeling. As a result, the focus for finding suitable short-term solutions to the quotation problem was placed on these product modeling -based workarounds. This subchapter presents the three available workarounds.

Approach A: Separate structures with manual linkages

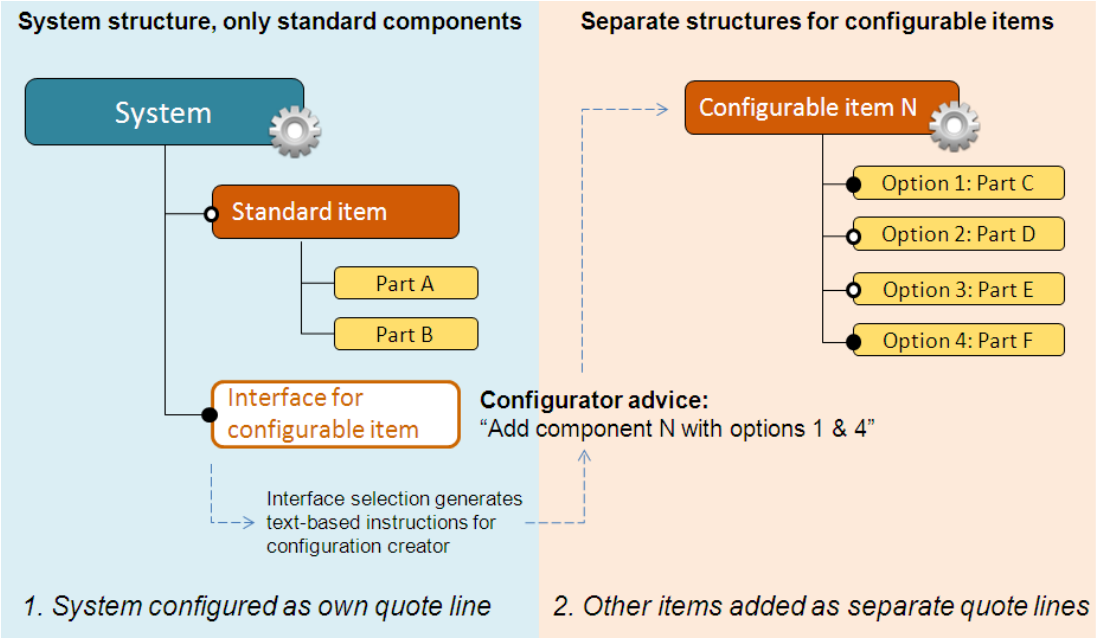

Figure 35 – Illustration of system product modeling approach A

The first possible approach for system product modeling in Case Company's current configuration environment is to use separate structures for each configurable item. This approach is based on the currently used, problematic way to structure systems (as nesting the configurable items inside system BOM is not allowed by the sales configurator). The problem of lack of glue between these separate structures is solved by creating manual, text-based linkages between system's components during the quote creation phase: Although the system structure can only contain standard

(non-configurable) items, the system BOM contains empty items that represent the to-be-added structures: when this type of empty item is selected when configuring the standard options of the system products, the sales configurator view provides advice for the configurer on which configurable item should be separately added to the quote. As a result, a complete system quote with each needed item can be created, although somewhat indirectly. The practice of creating a system quote with approach A is presented in Figure 35 above.

Approach B: Configurable components fixed as standard items

The second possible system structure approach is based on the notion that in system business level, there is no need to provide as wide component variability to the customers than in direct component sales (for a theoretical review on the subject, see e.g. subchapter 2.4.3). As the limitation of nested configurability forces systems to be built from standard items, the idea of this approach is to create needed standard configurations from configurable items: in other words, certain item configurations are fixed as new standard items, which can then be freely used within system structures. Further, there can be multiple fixed configurations of a certain configurable item to match wider range of customer needs. The approach of creating fixed items and using them inside system structures is illustrated in Figure 36 below.

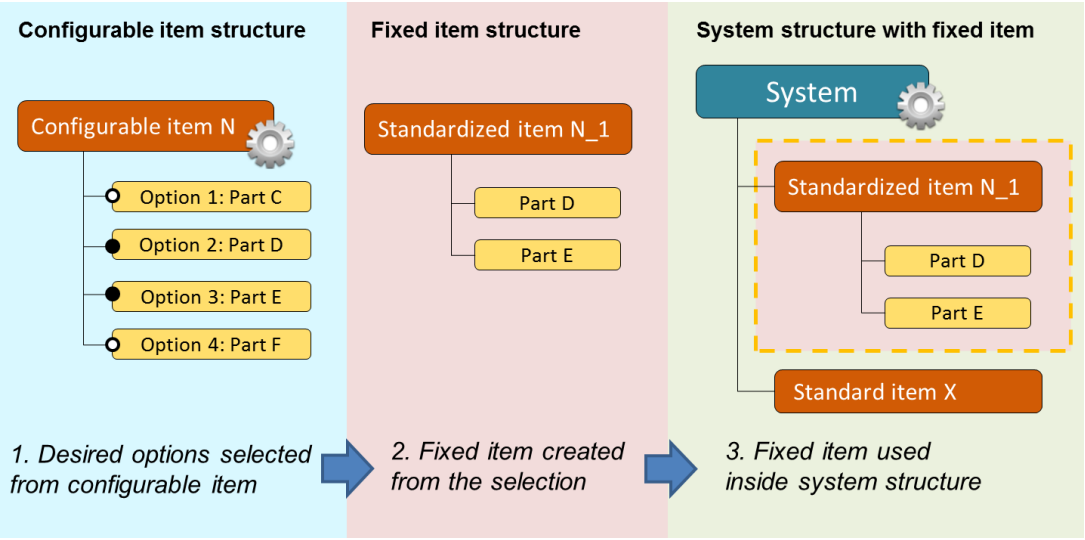

Figure 36 – Illustration of system product modeling approach B

Approach C: Virtual sales frame over separate structures

The third possible approach for system modeling is based on the theory-supported idea (see subchapter 2.2.2) that sales phase requires almost completely different view to the system products than manufacturing: in other words, abstract-level sales BOM and technical-level manufacturing BOMs should be separated from each other. This approach has not been previously used in Case Company as the sales configurator does not support automated conversion from one (sales) BOM to another (manufacturing). However, it is nevertheless possible to create the separated product views, if the conversion between the BOMs functioning in the background is done manually. Thus, this approach includes creating a sales-friendly "virtual" frame of empty reference items, which is used as the basis of sales configuration creation. After the quote has been made, there is a manual conversion phase from the virtual sales items to the referred technical items needed in manufacturing. The virtual frame and the quote-order conversion are illustrated in Figure 37 below.

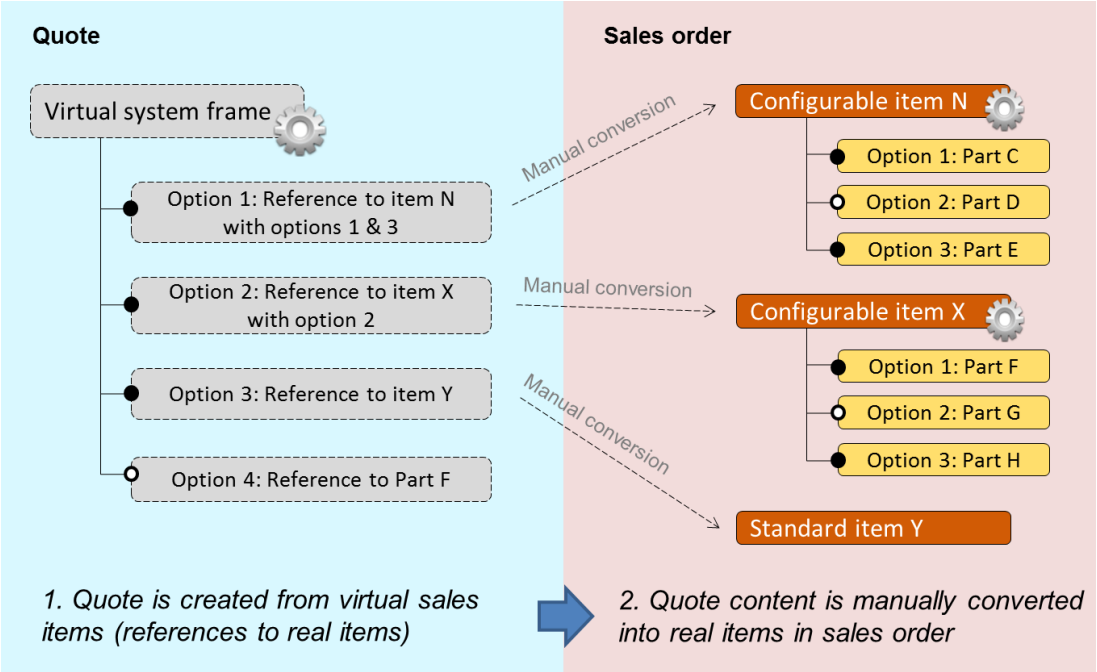

Figure 37 – Illustration of system product modeling approach C

5.3.2 Evaluation of approaches along the sales-to-delivery process

To be able to select the best alternatives for different cases from the presented approaches, a comparative evaluation criteria need to be defined. As was discussed

during the theory part (see e.g. subchapter 2.1.2), product structure solutions affect the whole configuration process: thus, the evaluation of the available approaches is done by studying the approaches' consequences to each different phase of the overall process, including process elements of sales-to-delivery, product creation, and reporting data usage. There configuration process elements are highlighted with (black, green, and blue) arrows in the Figure 38 below. More specifically, the process phases can be grouped into four areas: product management (green blocks), quote and order creation (orange), production (yellow), and business reporting (blue).

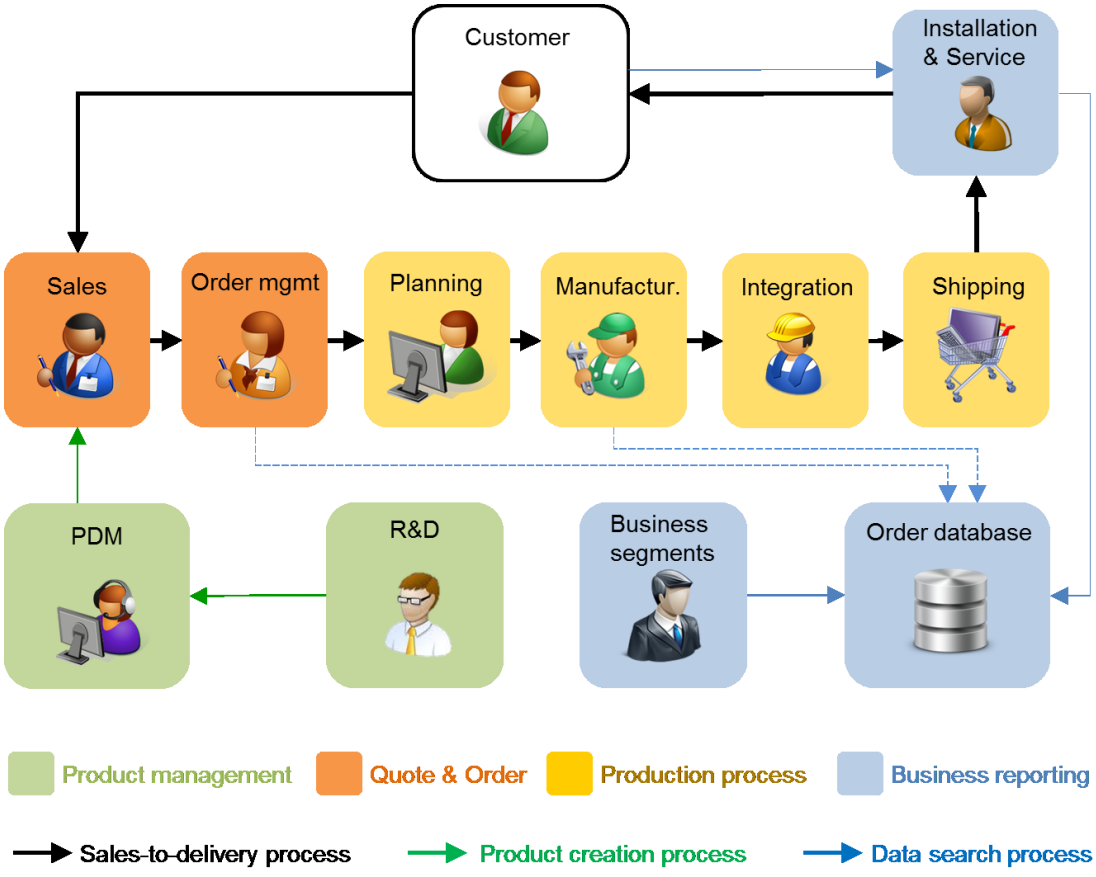

Figure 38 – Product configuration related process phases of Case Company's system business

From the configuration point of view, the most important phases of this general process are sales and order management blocks, as these phases are at the heart of configuration tasks: they take the system and product structures as an input from the product management phase, and create producible specifications as an output to the production phase. However, as discussed, the efficiency and fluency of these other phases, including also the business reporting phase which directly uses the data

created in the quote and order phase, are also important elements for the overall approach evaluation. The evaluation of the three system modeling approaches based on these four process areas is presented in the next subchapters.

Overall evaluation of approach A

The major strength of the approach A (separate structures) is its full customizability in quote creation phase: as the configurable products structures are directly used, the sales configurer has "free hands" to create a highly tailored solution for the specific customer needs. Other strengths of this approach include (1) easy item data management, as there is no need for any new structures or items, (2) possibility to continue currently functioning production practices, and (3) correct component-level reporting data, as there are no system-specific new items used. These strengths and the next discussed weaknesses of this approach per configuration process phase are presented in Table 3 below.

Table 3 – System structure approach A: Pros and cons per process phase

Process phase	Pros	Cons
Product management	No need for new items	No single system structure
Quote & Order	Fully flexible quoting	Difficult and inefficient sales
Production process	Standard & flexible process	Components cannot be made-to-stock
Business reporting	Correct item codes sold and reported	System business valuation not possible
Summary	**+ Customizability & Flexibility** **+ Standard process**	**- Inefficient and risky quoting** **- Incomplete reporting data**

However, as was already discussed in the problem description subchapter, the primary weakness of this approach is the overly complex, technical, and thus inefficient quote creation phase. In addition, as there is no single system structure, there is no real glue between separate structures: this complicates entity management and e.g. splits the system sales data on multiple components, leading to difficulties in identifying which component was part of which system. Finally, as configurable

items are used directly, it is basically not possible to make them to stock (for delivery time requirement needs), as the needed configuration cannot be specified in advance.

Overall evaluation of approach B

As is aimed with the idea of fixed system component configurations, the major strength of this approach is the ability to insert all system components into a single system structure. This possibility leads to multiple benefits: (1) system quotes can be made at once within a single sales view, while the quote creation task is also considerably simplified through these preconfigured items, and (2) the system business valuation becomes easier as all system components are under the same parent item. In addition, as these fixed components are standard, they can be made-to-stock for fulfilling the possibly strict delivery time requirements. These strengths and the next discussed weaknesses of this approach per configuration process phase are presented in Table 4 below.

Table 4 – System structure approach B: Pros and cons per process phase

Process phase	Pros	Cons
Product management	All-in-one system structure	Need for many almost-duplicate items
Quote & Order	Efficient quote creation	Limited customizability
Production process	Fixed items can be made-to-stock	Inflexible change management
Business reporting	System business valuation easy to get	Component sales valuation difficult
Summary	**+ Efficient quoting, better pricing** **+ Possibility to make-to-inventory**	**- Complicated product management** **- Inflexibility (quoting & process)**

However, as can be predicted, there are multiple challenges as well with this approach: First, product management of the component level becomes significantly more complex, as the configurable item and its each fixed version need to be simultaneously maintained. Then, it is natural that as "fixed items do not flex", the customizability of quote creation becomes considerably limited. In addition, using an all-in-one system structure slightly complicates the change management of the production process, as it is not possible to manage different items (which are e.g.

produced in different teams) as separate entities. Finally, the visibility to system component sales numbers is more limited, as the price of the system would not anymore be split into standard system and configurable components.

Overall evaluation of approach C

The third approach, creating a virtual sales frame which is manually converted to technical specification, provides the most simplifying alternative for quote creation among the three approaches. As the used virtual items can be specifically designed for the needs of sales, the quote creation can be significantly streamlined by providing just the information customers typically want to see. In addition, as the quoted sales items are converted to real technical items to the sales order, the rest of the process can be implemented similarly than currently, with normal manufacturing and data storing practices. These strengths and the next discussed weaknesses of this approach per configuration process phase are presented in Table 5 below.

Table 5 – System structure approach C: Pros and cons per process phase

Process phase	Pros	Cons
Product management	Usage of existing configurable items	Need to create / maintain virtual items
Quote & Order	Easy quote creation	Manual quote-to-order conversion
Production process	Standard & flexible process	Components cannot be made-to-stock
Business reporting	Correct item codes sold and reported	System business valuation difficult
Summary	**+ Easy quoting (virtual sales items)** **+ Standard process & No new items**	**- Manual quote conversion workload** **- Reporting data mostly scattered**

However, as discussed, the major weakness of this approach is the need for manual quote-to-order conversion: the conversion task is somewhat laborious, taking multiple hours in some cases. Also, the need to create, update and synchronize the virtual frame and its item references leads to more product management work. Further, as the stored sales order consists of normally priced real items, using a virtual frame does not help in getting an overall report for system business value.

Finally, as configurable items are used, they cannot be made-to-stock, even if the delivery time requirements were strict.

5.3.3 Suitability of approaches to different offering groups

As each of the three approaches has its own shortcomings, it was clear early on that a perfect solution will not be found among these alternatives. However, as they are basically the only readily implementable options for the short-term future, this subchapter aims to identify which of the available approaches provide the best short-term enhancements for system product configuration. More specifically, as Case Company's system product offering is somewhat versatile, the separate systems have also highly varying configuration needs; consequently, the suitability of each system modeling approach is analyzed for each identified system offering group.

Identified system offering groups and configuration-related needs

As was illustrated in the beginning of this chapter (see Figure 30 in page 55), Case Company has business in three offering levels; more specifically, the two highest levels contain system products, either in direct sales (system level) or as part of larger systems (bundled system level). When analyzing the configuration-related needs different system products within these levels had, it was identified that most of the bundled systems shared similar characteristics; meanwhile, the offering level of (single) systems had two clearly distinctive groups, customizable and productized systems. The customizable systems were targeted for high configuration needs, for customers who specifically require specifying all the low-level technical details of the systems' components. On the other hand, the productized systems were designed for customers requiring high efficiency, such as short lead times, medium-high level of abstraction (e.g. no need to specify component details), and somewhat lower price.

The three identified system offering groups, including their configuration-related characteristics, are illustrated in Figure 39 below. The four used characteristics include needs for component (product) level variability, quote abstraction level, and lead times, and the frequency of sales orders. As can be seen from the figure, bundled systems had the highest quote abstraction needs, less need for component variability, lowest sales volumes, and no need for particularly short lead times. Then, as discussed, there was clear distinction between the characteristics of these groups:

customizable systems were quoted less often and with higher detail level, while the productized systems had frequent sales orders, higher level of abstraction, and typically a need for short lead times.

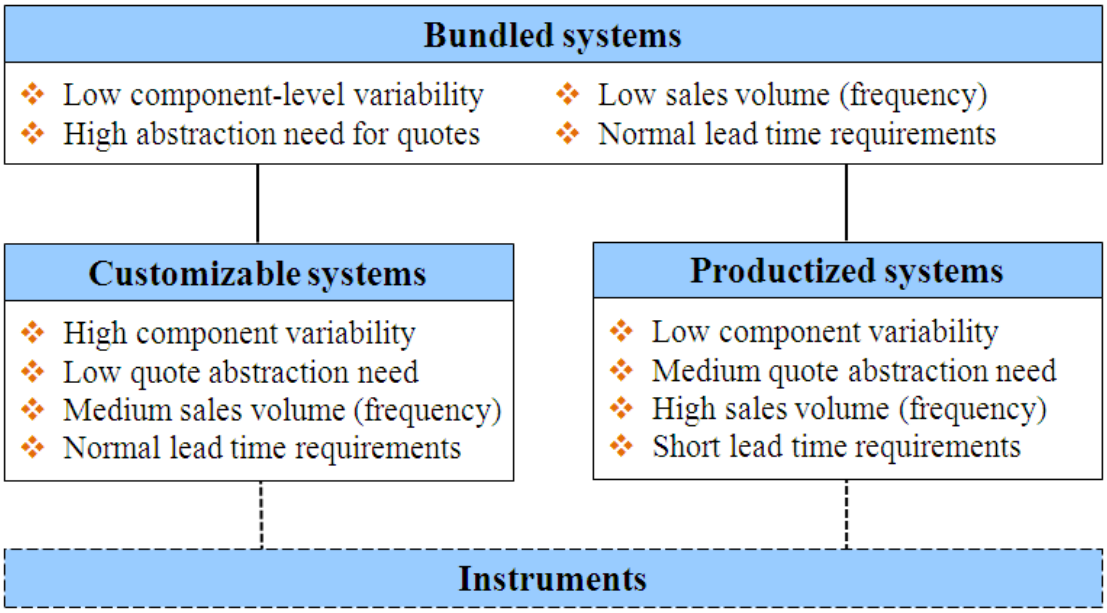

Figure 39 – Identified system offering groups and their configuration-related characteristics

Matching offering group needs and modeling approach capabilities

In the above section, it was identified that Case Company's system offering is split into three groups: bundled, customizable, and productized systems. Further, as presented previously, there are three currently supported approaches for system product modeling: (A) separate configurable structures, (B) fixed, non-configurable structures, and (C) virtual sales structure. To match the offering group needs with the capabilities of these system modeling approaches, a comparative criteria is needed. As there are four most important configuration-related categories that vary across the offering groups, the support that the system modeling approaches can provide for each respective category needs to be determined. As can be seen from the Figure 40 below, these support capabilities were abilities to configure system components, hide quote's technical details, create both quote and sales order easily and efficiently, and use make-to-stock components (presented in the orange boxes). The modeling approaches were given the below presented attributes directly based on the results of the previous pros and cons analyses (Tables 3-5).

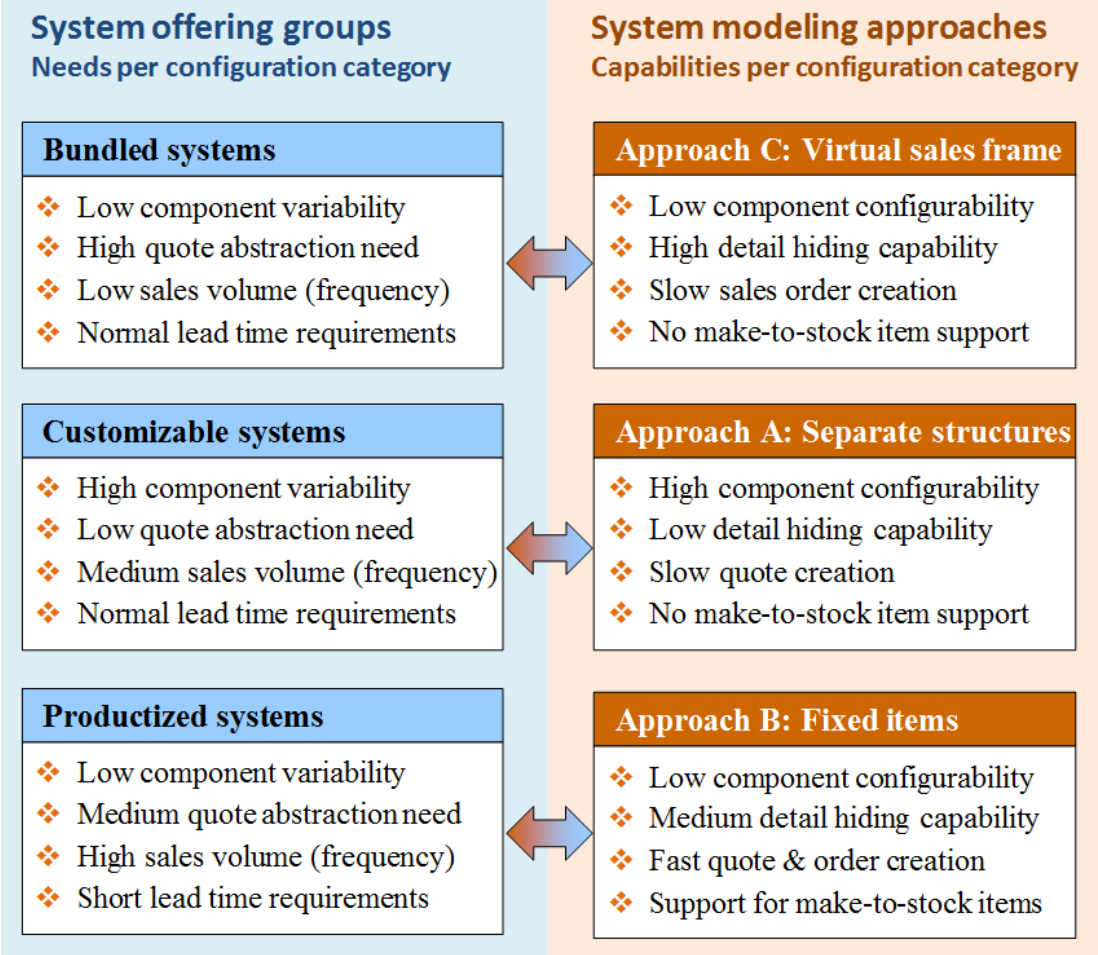

Figure 40 – The most suitable matches between system offering groups and system modeling approaches

Further, as the offering groups and modeling approaches consequently had been evaluated based on comparative criteria, the best matches between the groups were somewhat straightforward to identify, as presented above: As bundled system level required the highest level of simplification (abstraction) for quote creation and low component variability, it was matched with the virtual sales frame approach (C); it provided the best support for high abstraction. Although the virtual frame included a significant shortcoming of manual quote-to-order conversion, this workload was not a major issue for bundled level's low sales volumes. Then, for customizable systems' high variability needs, the separate structures approach (A) was the best alternative for providing wide enough configurability: despite the approach's major efficiency shortcomings, it was identified to be the only option for this basically free system component configurability range need. Finally, the productized system group was

matched with the alternative providing the highest overall efficiency; the fixed items approach (B).

Overall, although naturally desired, it was clear that a "one size fits all" approach could not be suggested. Each of the three modeling approaches had their own strengths and weaknesses, and especially the weaknesses would have grown overly large if tried to match with all system offering groups: approach C's manual conversion need was identified to be unacceptable for both system level groups; approach B's fixed item principle could not be applied for high configurability cases, since it would have complicated item management vastly; finally, approach A had multiple efficiency problems (as discussed in the problem description subchapter), and could not be suggested to any case outside the highest configurability needs.

5.4 Recommendations: Short- and long-term

This subchapter provides recommendations on how could Case Company enhance its currently difficult system product quote creation practices. The subchapter is divided into short- and long-term considerations: first, a summary of the previously evaluated system product modeling approaches is presented as the short-term solutions, and second, possibilities for further developing the overall configuration practices as the long-term considerations.

5.4.1 Short-term: Suggestions for solution approaches

Generally, it should be highlighted that the system modeling approaches investigated are not especially feasible long-term solutions: as each of them have their own, somewhat significant challenges in different configuration process phases, they should be only applied as "the best approaches available today"; in the longer term, more sophisticated system quote creation alternatives should be taken, to ensure efficiency along each phase of the whole sales-to-delivery and other related processes. However, as Case Company's system business requires enhancements already in the short-term, the following actions should be taken to enhance the current situation of system quote creation:

1. **Create fixed item configurations** to be used in productized systems
2. **Create virtual sales frames** to be used in bundled systems

In addition to these two approaches, the current quote creation approach of keeping configurable structures separated should be continued with systems requiring high customizability. Overall, there are no major risks when following these suggestions: both suggested approaches are already successfully tested with preliminary pilot systems. In addition, although adopting these approaches will lead to certain changes in multiple process phases, it was identified that the changes are relatively minor and can be implemented without any considerable investments.

5.4.2 Long-term: Considerations for configuration environment

As discussed, due to the limitations and challenges of Case Company's current configuration environment (including e.g. the used IT infrastructure and existing product structure implementations), no longitudinally feasible enhancement alternative was directly available. However, in the longer term, there are certain development possibilities that Case Company should consider to more completely enhance the problematic configuration process. First, it is critical to understand the real boundaries[4] of the sales configurator: more flexible product modeling approaches are certainly required in addition to the suggested short-term alternatives; nested configurability would especially be needed for components that integrate Case Company's products into customers' existing installation environment, as these variables typically differ case-by-case. Second, the currently available system modeling approaches should be developed further: especially the virtual sales frame approach (C), which was a correct step towards the theoretically optimal approach of using clearly separated sales and manufacturing BOMs, could be enhanced by automating the currently laborious quote-to-order conversion.

Further, as was discussed in the background subchapter (5.1.3), the evaluation of Case Company's configuration practices based on the previously established theoretical framework revealed certain shortcomings: given the product modeling limitations of the used ERP module sales configurator, actions of (1) system component standardization and (2) technical sales support usage should be taken.

[4] In fact, a more detailed analysis of the ERP's sales configurator capabilities revealed that the software itself would support nested configurability: the remaining major question is whether other related challenges such as process reorganizing would be feasible or not to execute.

However, Case Company had only limited implementation of both actions in place: (1) system components were mostly fully configurable, although more limited variability range would typically be enough for majority of customers, and (2) the number of used sales support personnel was tiny, taking into account the complexity of Case Company's system products. Overall, based on the mentioned issues, four long-term development steps are suggested:

Sales configurator development

1. **Start project for testing more flexible product modeling approaches:** The capabilities of the used ERP module sales configurator, such as nested configurability, need to be comprehensively investigated.
2. **Invest on automating quote-to-order conversion** in otherwise promising virtual sales BOM approach**:** required investments are estimated to be minor.

Configuration requirements development

3. **Broaden technical sales support:** Add resources for support, either by redefining sales / support personnel balance or hiring new personnel.
4. **Emphasize system component productization:** Without further system component standardization, any system modeling approach cannot fully solve the resulting complexity challenges.

In addition to these focused development targets, Case Company needs to also further discuss the feasibility of the used sales configurator software in general: Is it optimal to try to live with the undeniable challenges of this ERP module solution? Or should a dedicated sales configurator tool be considered to better fulfill the needs of system business (as the needs differ with the product business)? As there are numerous possible implementations, a comprehensive study of suitable sales configurator alternatives is needed to be able to answer the question in an optimal way for Case Company's specific corporate setting. In addition, as the example of Benchmark Company 2 showed, conducting this type of comparing study with emphasis on the company-specific system configuration needs can optimally lead to outstanding configuration practices.

6 Discussion

This chapter discusses the key topics of this study by combining findings from both the theoretical review and the extensive Case Company study. Most importantly, an extension for the previously established theoretical framework is proposed based on the practical, short-term enhancement actions used in the Case Company. Further, the general applicability of this extended framework is discussed.

6.1 Case Company -based extension for the theoretical framework

When analyzing the system sales configuration practices of the Case Company, it was found that the previously established theoretical framework did not fully apply to the corporate case. Although the suggested enhancement actions of the framework were found to be relevant also for Case Company, it was identified that implementing these suggestions would be more of a long-term issue: broadening the sales support team and better standardizing the product offering were considered to be valuable recommendations as a development target for next few years, but not for the time being. As a result, to achieve enhancements already within the next months, the short-term development analysis was targeted on system product modeling development. More specifically, as discussed in the previous chapter, these short-term approaches related to creating BOM modeling workarounds for the current limitations of the used ERP module sales configurator: the two proposed approaches managed to bypass the modeling limitations of nested configurability and separated sales BOM support by building the system BOMs in an enhanced manner; removing the need for configurability in multiple BOM levels, or creating a virtual, artificially separated sales BOM on top of the production BOM proved to be successful short-term enhancements for Case Company's situation.

Thus, it was clear that a time dimension should be added to the established theoretical framework. The three originally identified enhancement actions were each found to be suitable for long-term considerations, while Case Company's approach of creating BOM modeling workarounds was discovered to fit short-term enhancement requirements for these ERP module sales configurator cases; the stand-alone sales configurators would not typically benefit from these workarounds, as

more sophisticated product modeling capabilities, including the ability to support multiple BOMs, were typically in place in the first place. Thus, the upgraded theoretical framework with this additional short-term BOM modeling action is formed as illustrated in Figure 41 below.

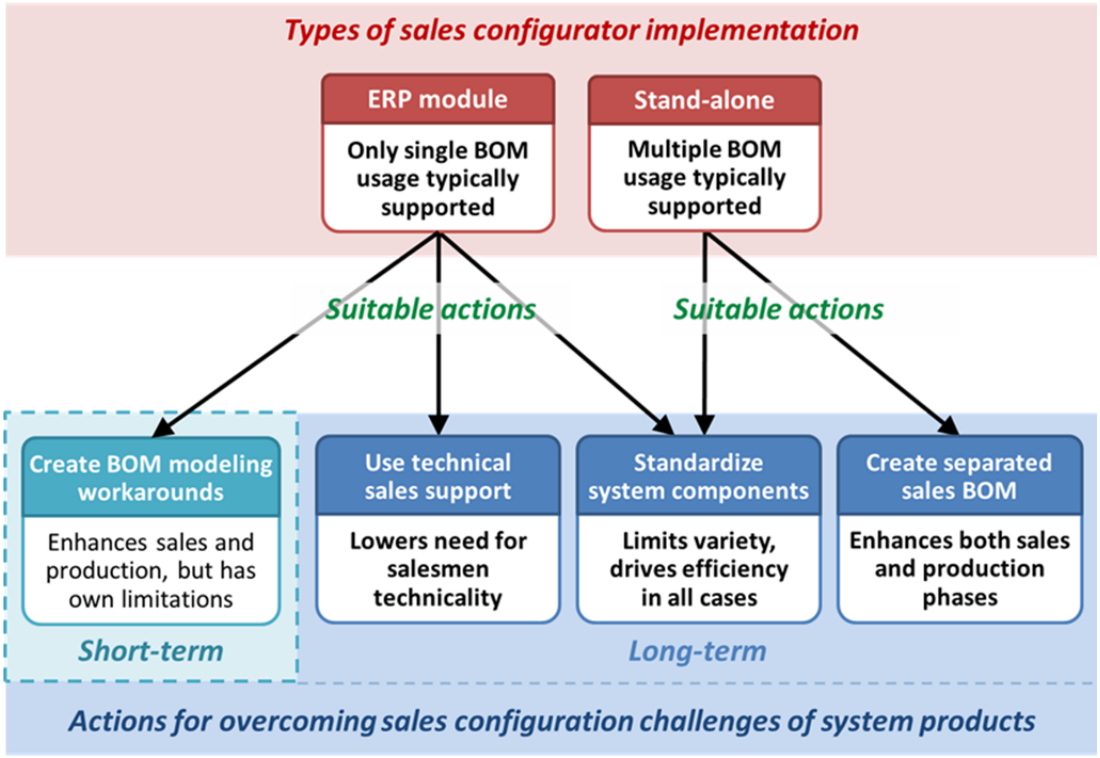

Figure 41 – Time-dimensionally extended theoretical framework for matching the sales configurator types and available system configuration enhancement actions

From the figure it can be seen that the previously established theoretical framework is extended to cover also the time dimension: the original action suggestions represent the long-term, while the additional BOM modeling action represents the short-term. More specifically, it should be highlighted that as the short-term approach of creating system BOM modeling workarounds is indeed a workaround, it has its own limitations and typically does not provide suitable approaches for longer-term usage. Overall, this extension, which was identified to be needed during the Case Company study, makes the theoretical framework more comprehensive and applicable for different situations. The further suitability of this framework is discussed in the next subchapter.

6.2 Applicability of the extended framework

The above figure presents the most central finding from this study: a framework for identifying the most suitable system sales configuration enhancement actions. More specifically, the suggested actions depend on the type of the used sales configurator. Thus, it aims to provide generalizable knowledge for both academic literature and managerial decision-making on what consequences a selection of a specific sales configurator type might have, and which actions should be taken. Thus, the general applicability of this framework needs to be discussed: as the framework was formed based on a limited amount of existing research on the issue and a small group of studied case companies, it is clear that there might be also other suitable enhancement actions for system product sales configuration. In addition, the identified capabilities and limitations of both sales configurator types are also based on limited number of evidence, as there were only two studies companies in each configurator type category. These limitations are further discussed in subchapter 7.2.2.

However, despite the mentioned limitations, there is definitely no reason to abandon the framework results as non-generalizable. The enhancement actions used in each of the four studied, rather large and successful Finnish companies matched almost fully with the actions proposed in the framework. Although the short-term actions were only discussed within one of the companies, especially the applicability of longer-term actions for the presented sales configurator types is believed to be somewhat high. Overall, it can be argued that the established framework successfully provides general guidelines for companies searching for remedies to their system sales configuration challenges.

7 Conclusions

This chapter provides a conclusion of the study and its findings. First, a summary of the key findings, related to both the research questions and the Case Company case, is presented. Then, the study is evaluated by discussing its contributions and limitations. Finally, certain future research topics are recommended.

7.1 Summary of the key findings

The purpose of this thesis was to identify successful approaches for efficient system product sales configuration. The emphasis was especially on companies which pursue a multi-leveled product offering, i.e. sales of both systems and systems' components. The study was conducted as a combination of literature review, three benchmark case company studies, and an extensive study of Case Company.

7.1.1 Findings related to the research questions

The main research question of the study was formulated as "*how should industrial companies use sales configurators in enhancing their sales-to-delivery processes of system products?* To comprehensively study the research question topic, three sub-questions were also formulated. The first sub-question, *"what are the general benefits and challenges of using sales configurators?"* was answered somewhat inclusively: multiple benefits and challenges were identified, and grouped into relevant categories. The most important benefits from applying a sales configurator most importantly included significantly raised overall process efficiency: more explicit and fluent sales configuration phase directly leads to enhancements in also the manufacturing phase, as the specifications need not to be separately validated or manually particularized. On the other hand, employing a sales configurator requires especially overcoming the challenges of restructuring products and organizational processes for configuration needs. In addition, the challenge of linking sales and production specifications to each other, beginning from the product modeling solutions, was also identified as a key factor to overcome.

The second sub-question, *"how should sales configurators be integrated with other corporate IT systems?"* was also somewhat well answered, although the findings were mostly limited to the company case studies. However, it was identified that the

configurator software needs to be properly interfaced with both PDM and ERP systems, as they typically store all the configurator inputs, provide supporting information along the configuration process, and use the configurator output as the basis for production. More specifically, the investigation was targeted on two types of sales configurators, stand-alone and ERP module, as the integration need to other IT systems depended heavily on the selection. It was identified that if the more closely integrated alternative, ERP module sales configurator was used, the system product modeling capabilities were typically limited; on the other hand, the stand-alone alternative tended to support better modeling functionalities, but experienced difficulties in fully interacting with the other IT systems. It was concluded that the recommended selection between these alternatives is highly case-dependent; however, stand-alone sales configurators typically suited better for the needs of complex products (such as systems), while the ERP modules supported well more standardized and simple structures.

The third sub-question, *"what special characteristics are related to achieving efficient sales configuration of complex, configurable system products?"* was answered rather comprehensively, despite limited amount of research covering the issue. The most important finding was the sales configuration complexity of systems: thus, the need for actions to simplify this complexity was highlighted. More specifically, it was identified that enhancing system product sales configuration requires not only fulfilling the general configuration requirements (e.g. product and process realignment) and sales configurator type selection, but also the adaptation of certain company-specific enhancement actions: system component standardization, suitable system modeling solution creation, and technical sales support usage. The suitability of these actions was found to depend on the used sales configurator type: both cases benefited clearly from the component standardization, but ERP modules typically did not support as sophisticated product modeling solutions than stand-alone alternatives, leading to a need for technical sales support.

Overall, the main research question was answered successfully: with system products, sales configurators should be used by fully utilizing and developing their product modeling capabilities. More specifically, if a separated sales structure can be

created for system products, their sales configuration task simplifies considerably, while still retaining explicit linkages to technical specifications needed in manufacturing. Further, if the sales configurator does not support this separation, there are basically three available options: (1) simplifying the sales configuration task by standardizing needed system components, (2) supporting the complex sales configuration task by applying sufficient technical sales support personnel, and (3) managing the sales configuration task with other, less sophisticated product modeling solutions (as was done in Case Company).

7.1.2 Findings related to the Case Company

In addition to answering the research questions, this thesis aimed to provide recommendations for enhancing the system product sales configuration practices of the Case Company. As was presented in subchapter 5.4, both short- and long-term recommendations were given, based on both the numerous interviews conducted in the company and the established theoretical framework for system configuration enhancements. The key company-independent finding of the Case Company study was that in addition to the theory-based action recommendations, industrial companies might also need more instantly implementable remedies for their system sales configuration challenges: the theory based suggestions of (1) better standardizing system products' components, (2) applying a larger technical sales support team, or (3) even employing totally new (stand-alone) sales configurator software might take years to be successfully implemented; thus, the need for shorter-term enhancements is clear, and specifically in the Case Company, the somewhat immediate impact could be made through system product modeling development.

Although the discussed product modeling approaches were company-specific solutions, it is likely that the same idea can be applied in multiple other corporate cases pursuing somewhat similar IT infrastructure and product structures as well: e.g. the benchmark case of Benchmark Company 3 had similar configuration setting than Case Company; had they not already remedied their sales configuration tasks through technical sales support usage, the approach of product modeling development would have likely been suitable for this company case as well. Overall, the Case Company study highlighted the notion that even if (any) used sales configurator does not fully

support separating sales and production BOMs, the product modeling approach should not be abandoned: within any configurator software, there are some modeling limitations, which need to be remedied by one way or another.

7.2 Evaluation of the study

This subchapter provides an evaluation of this study. First, the academic and managerial contributions of this study are presented, and second, the study's limitations related to the information sources and methods are discussed.

7.2.1 Academic and managerial contributions

The findings of this study provide several contributions to both the existing academic literature and managerial decision-making in general. Academically, the most important contribution of the study is the established theoretical framework (see Figure 29 in page 53): the identification of different sales configurator types and especially the analysis of the types' typical capabilities provided previously unexamined building blocks for filling the considerable literature gap on sales configurator usage. Further, identifying suitable actions to overcome system sales configuration challenges for both sales configurator types was a significant contributive starting point for literature studying how companies should operate given their existing configuration-related IT infrastructures. In addition, the study provided new knowledge on the special characteristics of system product configuration in general, and especially the challenges which the existence of multi-leveled product offering poses for configuration. The literature on the latter viewpoint was basically inexistent, thus making the identification of these challenges and their possible enhancement approaches academically valuable.

Managerially, the study contributed especially by providing general guidelines on which type of sales configurator typically is the most suitable alternative for companies offering system products. In addition, the identified enhancement actions for these types provided general recommendations on which approaches companies should take to make the sales-to-delivery process of system products more efficient. In addition, as was also found through the small amount of available research on the topic, the issue of sales configuration in general is not yet comprehensively understood: thus, analyzing four different real company cases provided valuable

comparative knowledge for managers searching for the most optimal sales configurator solution for their specific company needs. Overall, it can be said that the findings of this thesis form an important background for both further academic studies, and managerial sales configurator related decision-making.

7.2.2 Limitations

There are multiple limitations related to the conducted study, relating to both limited amount of existing research on the thesis topic and limited number of studied companies. First, the existing research on sales configuration of system products was surprisingly limited: the topic of sales configurators was only even discussed by few researchers, including Forza et al. (2006) and Arana et al. (2007). Similarly, the research on the role of configurators in the corporate IT infrastructure basically included only two works: Tiihonen et al. (1997) on PDM's and Jardim-Gonçalves et al. (2007) on ERP's interaction with the configurator software. Further, also the research on system product configuration and multi-leveled product offering was almost non-existent: to gain knowledge on system product configuration, studies of system products (e.g. Davies et al., 2007) and product configuration (e.g. Tiihonen, 1999) needed to be covered separately and self-combined. The same challenge applied to multi-level product offering investigation: the idea of selling products in different offering levels was only touched in few articles (e.g. Hobday et al., 2005). As a result, the generalizability of literature-based findings on system product sales configuration in the presence of multi-level product offering is considerably limited.

As there were many research topics without proper studies, the conducted company case studies were aimed to fill this gap. Although these cases provided extremely valuable knowledge for the topics covered, it needs to be remembered that the number of studied company cases was only four: especially, as three of the case companies were only interviewed once or twice, it is more than likely that the findings are case-specifically biased; an implementation functioning well with one company might not suit at all for another. Particularly, as the topic of sales configuration is considerably versatile, touching basically all the corporate functions from IT infrastructure to sales-to-delivery process, generalizable findings from few company cases are difficult to propose. Finally, although over 80 interviews were

conducted within the Case Company, the study topic was somewhat limitedly discussed in the company previously: thus, the identified feasibility of the discussed short-term approaches was mostly based on individual employee's opinions; thus, it is likely that the interpretations of the conducted interviews are slightly biased.

7.3 Future research topics

As can be seen from the above discussed study limitations, there are multiple research topics that should be more comprehensively studied in the future: most importantly, as the research on the thesis' topic of system product sales configuration is considerably limited, there is a vast need for studies of general sales configurator usage and system product configuration. Especially further knowledge from real corporate cases would provide significantly valuable information for this research area. In addition to studying the system product sales configuration topic with a larger company sample, there is also a clear need for more detailed analysis on the differences of stand-alone and ERP module sales configurators and their capabilities: this study identified certain characteristics for these configurator types basing on only two company cases for each type.

The issue of needed configurator capabilities is especially important with system products, as their complexity typically clearly reveals the shortcomings of the specific sales configurator solution. Finally, extending the coverage to system products is not enough in itself to fulfill the identified research gaps, as the discussed system product configuration challenges especially related to the presence of multi-level product offering: if a company is only selling system products, it is considerably easier to establish efficient configuration practices for them than if also the systems' components would be manufactured and sold to customers. Thus, there is a significant need for identifying companies with this type of leveled product offering, and focusing study interests on the sales configuration practices these companies pursue with their system products.

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Appendix

Appendix 1: List of Case Company interviews

Table 6 – List of conducted interviews in Case Company

Company group / Interviewee position *(interviews dated between January and August 2012)*	**Number of interviews**
Product management	**22**
Product managers, bundled systems	6
Product managers, systems	8
Product managers, products	2
Product area manager, systems	3
R&D engineers	3
Sales & order management	**10**
Sales persons, bundled systems	3
Sales persons, systems	3
Sales support manager, systems	1
Team leader, order management	1
Order coordinators	2
Production process	**12**
Process engineers	4
Production planners	2
System design experts	2
Team leader, system integration	1
Team leader, system manufacturing	1
Team leader, product manufacturing	1
Team leader, system shipping	1
Business reporting	**10**
Installed base experts	7
BI-reporting expert	1
Offering manager	2
IT tools	**27**
PDM / configurator experts	16
ERP experts	11
Total	**81**

Appendix 2: List of benchmark interviews

Table 7 – List of conducted interviews in the benchmark companies

Company / Interviewee position *(interviews conducted during summer 2012)*	**Number of interviews**
Benchmark Company 1 (conducted on June 6th 2012)	**1**
Configurator team leader	1
Benchmark Company 2 (conducted on June 21st 2012)	**1**
Head of sales systems & Sales configurator concept owner	1
Benchmark Company 3 (conducted on July 30th and August 6th 2012)	**2**
Head of pricing management	1
Manager, pricing & item data	1
Total	**4**